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A COMPENDIUM OF NASA AEROBEE SOUNDING ROCKET LAUNCHINGS FOR 1964

BY
JON R. BUSSE
MERRILL T. LEFFLER
GEORGE E. KRAFT
PAUL S. BUSHNELL, JR.

DECEMBER 1965



— GODDARD SPACE FLIGHT CENTER —
GREENBELT, MARYLAND

PRELIMINARY

A COMPENDIUM OF NASA AEROBEE
SOUNDING ROCKET LAUNCHINGS FOR 1964

By

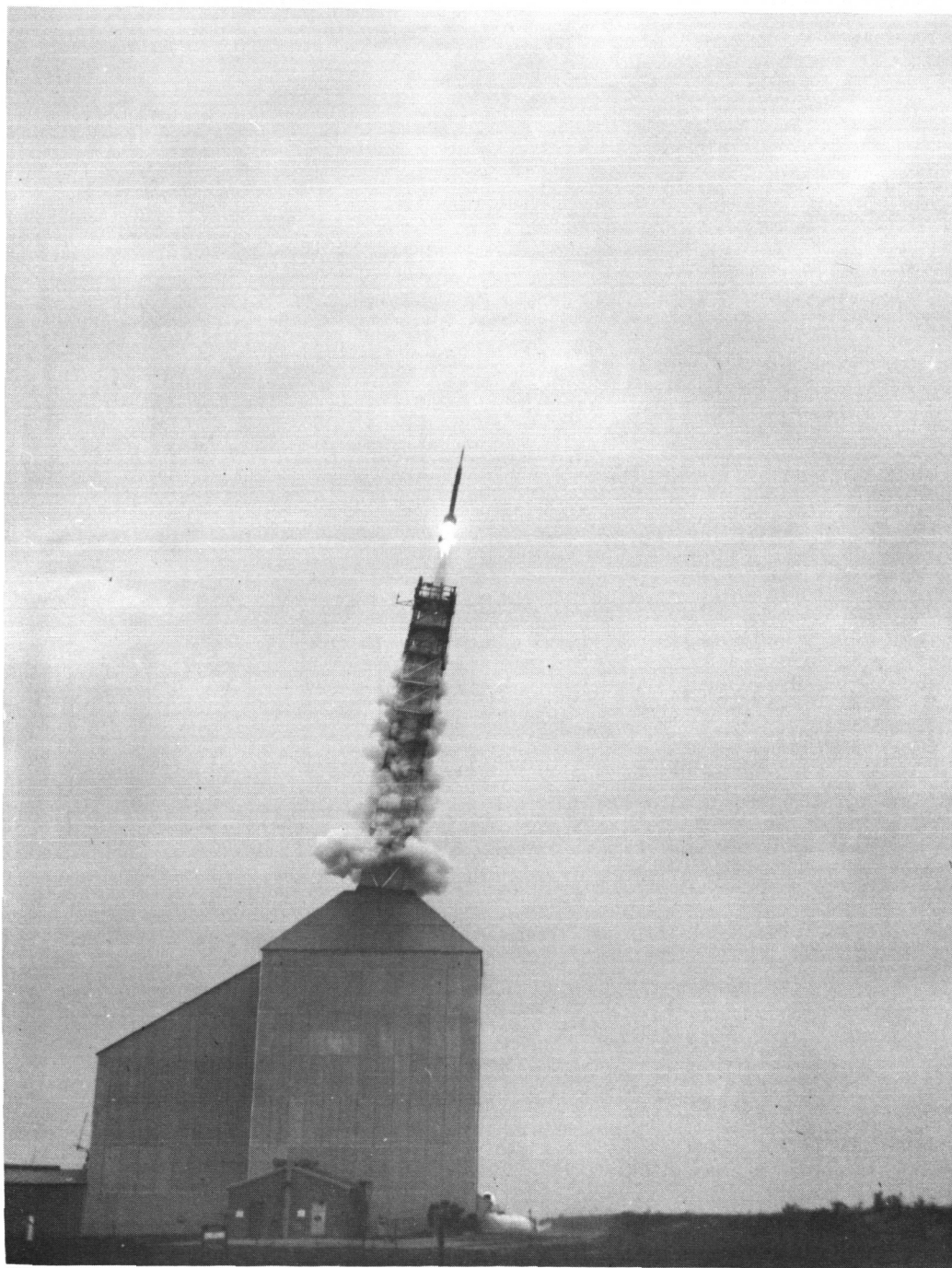
Jon R. Busse
Merrill T. Leffler
George E. Kraft
Paul S. Bushnell, Jr.

GODDARD SPACE FLIGHT CENTER
Greenbelt, Maryland

CONTENTS

	<u>Page</u>
SUMMARY	1
INTRODUCTION	1
AEROBEE SOUNDING ROCKET RESEARCH	1
THE AEROBEE SOUNDING ROCKET VEHICLE	2
CHRONOLOGY	6
Flight 4.88 GT	7
Flight 6.09 GA	9
Flight 4.124 UA	9
Flight 4.15 GG	19
Flight 4.81 GG	23
Flight 4.86 NA	26
Flight 4.113 GA-GI	32
Flight 4.67 NP	37
Flight 4.107 GE	40
Flight 4.108 GE	43
Flight 6.10 GA	46
Flight 4.82 GG	47
Flight 4.126 GG	49
Flight 4.122 CG	51
Flight 4.55 UG	52
Flight 4.115 NA	55
Flight 4.13 GP-GT	57
Flight 4.120 GG	65
Flight 4.123 CG	66
Flight 4.116 GS	67
Flight 4.52 UG	70
Flight 4.109 GG	71
Flight 4.110 GG	71
Flight 4.118 NA	73
Flight 4.45 GA	76
Flight 4.83 GA	77
Flight 4.132 GA-GI	78
Flight 4.125 UA	79
CONCLUSIONS	80
ACKNOWLEDGMENTS	80
REFERENCES	81
BIBLIOGRAPHY	81
APPENDIX	
A. Cross Reference Index of 1964 Rocket Launchings	83
B. Performance Characteristics Charts	89
C. Index of Reduced Performance Data; 1964 Flights	93
D. Summary of 1964 Flight Statistics	97
E. Abbreviations and Definitions	103

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Aerobee 150 A Sounding Rocket 4.45 GA Launched from Wallops Island, Virginia

A COMPENDIUM OF NASA AEROBEE SOUNDING ROCKET LAUNCHINGS FOR 1964

by

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SUMMARY

A total of twenty-eight NASA Aerobee sounding rocket vehicles were launched during the calendar year 1964. For information concerning NASA Aerobee Sounding Rocket Launchings prior to 1964, see Reference 1, which provides summary information on actual performance data compiled for launchings during that period. The data presented in this report provides a view of overall Aerobee performance for 1964 which can be useful in evaluating past Aerobee performance capabilities. Additionally, this information is useful to all scientists who are interested in obtaining data on Aerobee sounding rocket vehicle performance.

INTRODUCTION

During CY 1964, the Aerobee vehicle continued to provide a workhorse capability for sounding rocket research. This report provides detailed information concerning each Aerobee launching achieved for the year. Although vehicle performance was marred in the 2nd quarter of the year by three consecutive Aerobee failures, the successes realized on subsequent launchings improved the year's vehicle reliability to 84%.

In the chronology section of this report, each of the twenty-eight flights in 1964 is analyzed, including reduced flight performance data where significant to the discussion. Two cross reference indices and another summarizing chart are provided in the appendix which can be useful in comparing overall statistics with each flight (Appendix D), or for cross referencing particular similarities between flights (Appendix A). Also included in the appendix are useful performance characteristic charts (Appendix B) and representative flight performance curves (Appendix F).

AEROBEE SOUNDING ROCKET RESEARCH

The Aerobee vehicle with its relative simplicity and low cost provides an excellent method for the exploration of space from altitudes up to approximately 150 statute miles. It is economical when compared to more expensive satellite programs. These features, and others, make the Aerobee a popular vehicle for sounding rocket research by Goddard scientists, universities, colleges, and a variety of scientists (both foreign and national) interested in the wealth of scientific knowledge available through sounding rocket research.

In addition to providing new or small universities with a means for entering the field of space research, the Aerobee provides a great versatility. The Aerobee provides a relatively simple means of evaluating the degradation of orbiting satellite instrumentation; it provides an economic means for evaluating the performance of instrumentation to be used later in more expensive satellite configurations, thereby reducing the possibility of costly failures, etc. Though but a few, these examples serve to describe the increasing responsibility of the sounding rocket in space research.

THE AEROBEE SOUNDING ROCKET VEHICLE

The Aerobee vehicle is a two-staged liquid propelled, free flight rocket which is fin-stabilized and boosted from a launch tower by a 2.5 KS 18,000 lb thrust solid grained booster (nominal burning time 2.5 seconds). The sustainer portion of the rocket is ignited by the hypergolic action of 35% furfuryl alcohol and 65% aniline fuel mixture (known as AFNA) and an inhibited red fuming nitric acid oxidizer (known as IRFNA). The vehicle initially rides on top of the booster thrust structure during the 2.5 second boost phase of flight. The sustainer burns for approximately 51.5 seconds.

Different systems frequently included in typical rocket configurations are: a recovery system; a gas or yo-yo type despin system; a solar pointing control; and an attitude control system. Figure 1 shows a typical extension section. Extensions, which are used to house rocket instrumentation, are available in lengths of 6 to 75 inches.

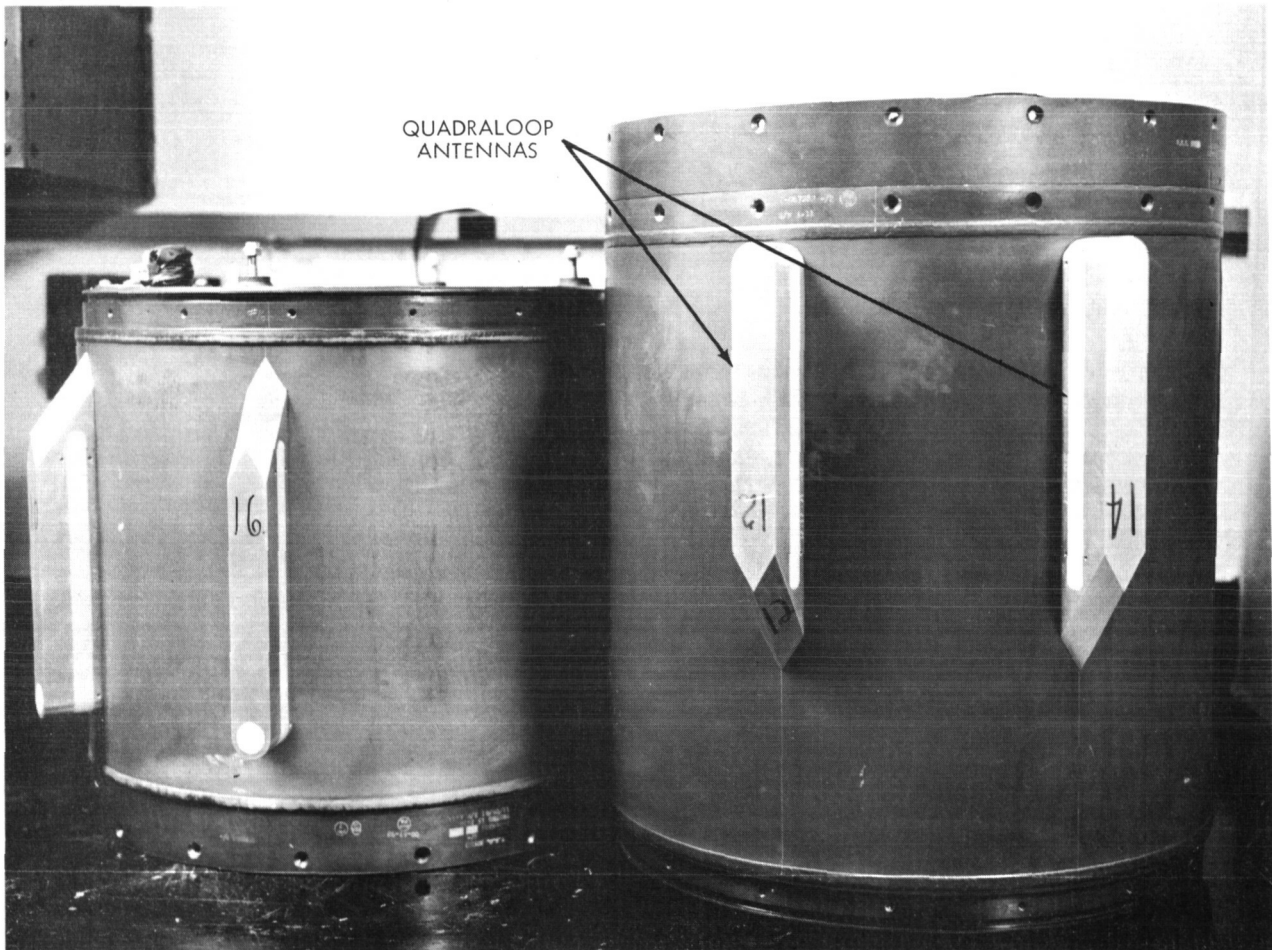


Figure 1. Typical Extension Section Used on Aerobee Rockets with Quadraloop Antennas Mounted to Outside

The fins are canted prior to flight to induce a roll motion in the rocket. This is necessary in order to reduce dispersion during flight. Figure 2a shows the service connections on an Aerobee 150 (without extensions); Figure 2b shows service connections with dimensional statistics for the Aerobee 150 A. Aerobees have been flown with either ogive or cone cylinder nose cones (See Figure 3).

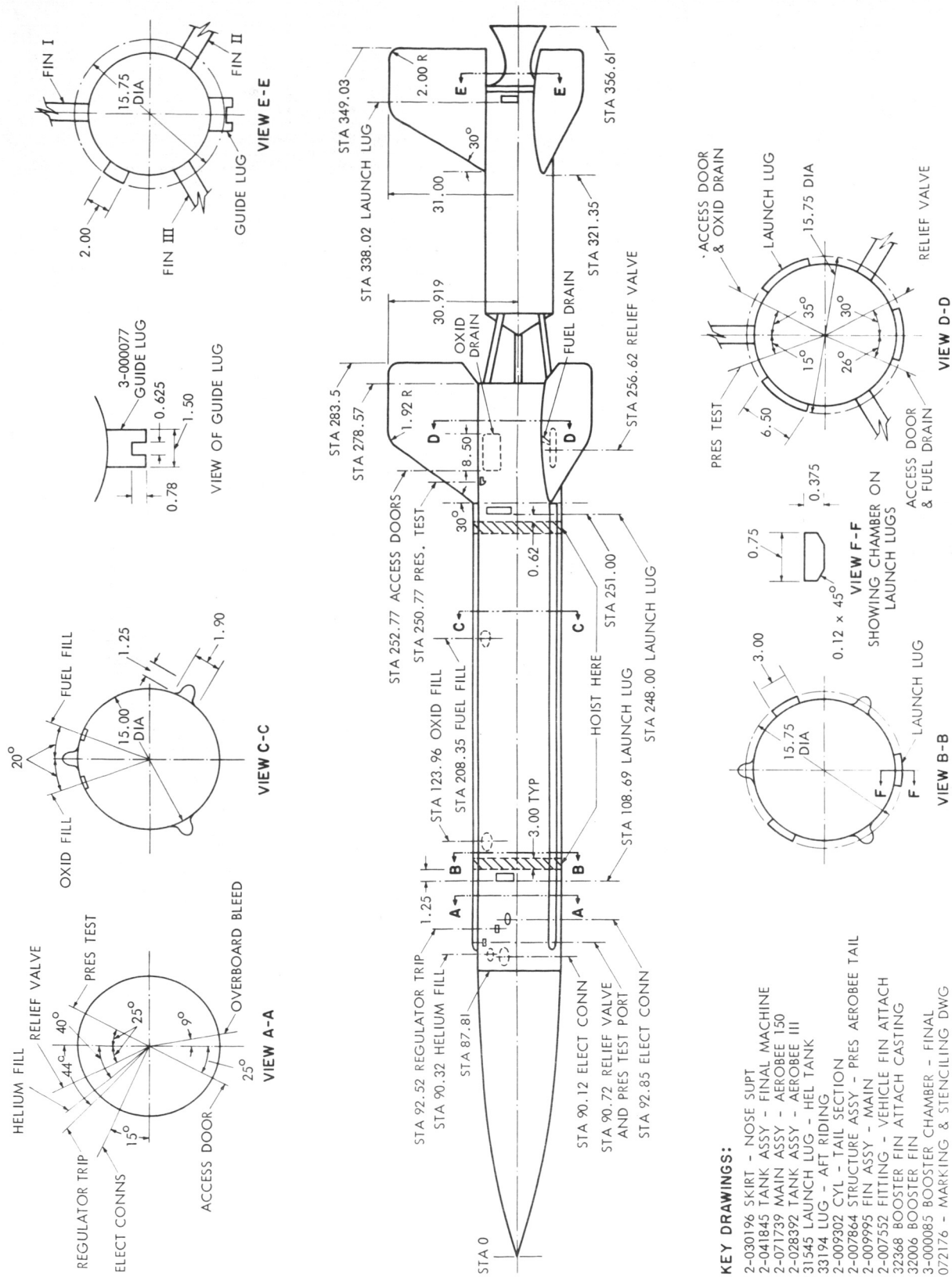


Figure 2a. Service Connections; Aerobee 150 Rocket

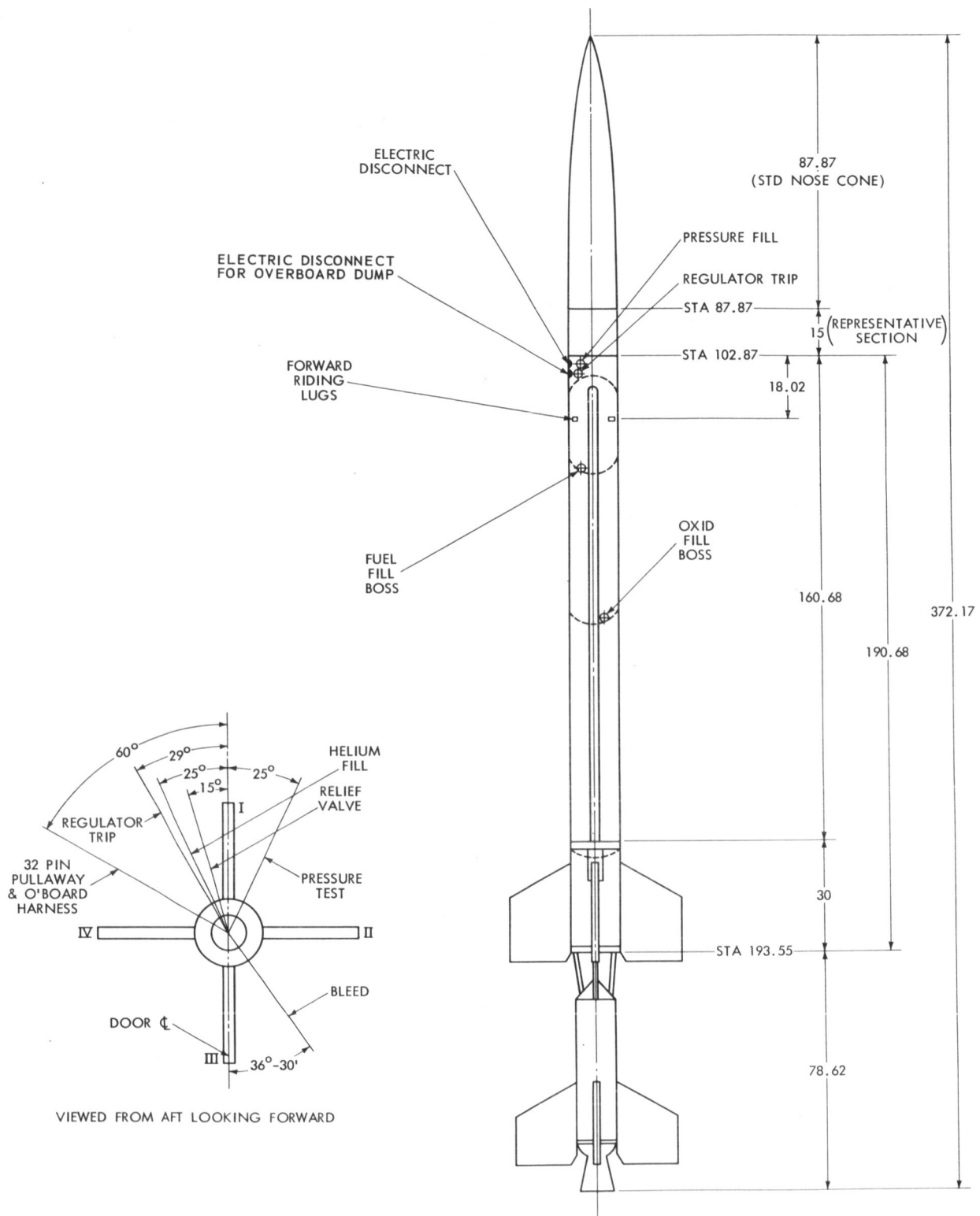


Figure 2b. Service Connections; Aerobee 150A Rocket

The induced roll rate at burnout for a typical Aerobee is 2.0 rps. For an Aerobee 150 with a 250 lb net payload weight and ogive nose cone the velocity at this time will be about 5870 ft/sec at an altitude of 128,000 feet. The expected peak altitude for this configuration is 128 statute miles. With the same configuration, but using a cone cylinder nose cone, the peak altitude will be approximately 4% less.

Four-fin Aerobee 150 A's are only launched at sea level from the enclosed tower at Wallops Island, Virginia. Similarly, the Aerobee 300 A, a four-fin Aerobee, with an additional third stage, is launched only from Wallops Island. These configurations are very similar to the three-finned Aerobee 150's launched at the White Sands Missile Range, New Mexico (see Figure 4) and at the Churchill Research Range, Canada, and to the Aerobee 300's currently launched only from Ft. Churchill.

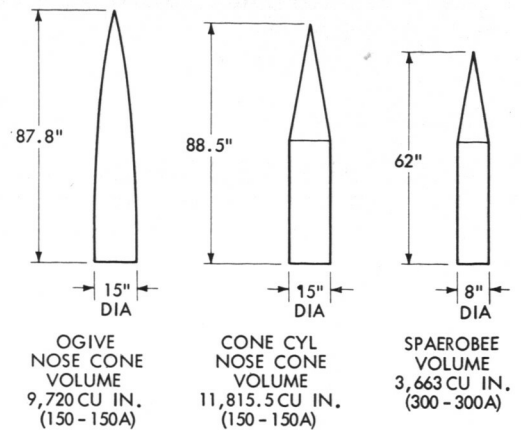


Figure 3. Aerobee Rocket Payload Configurations

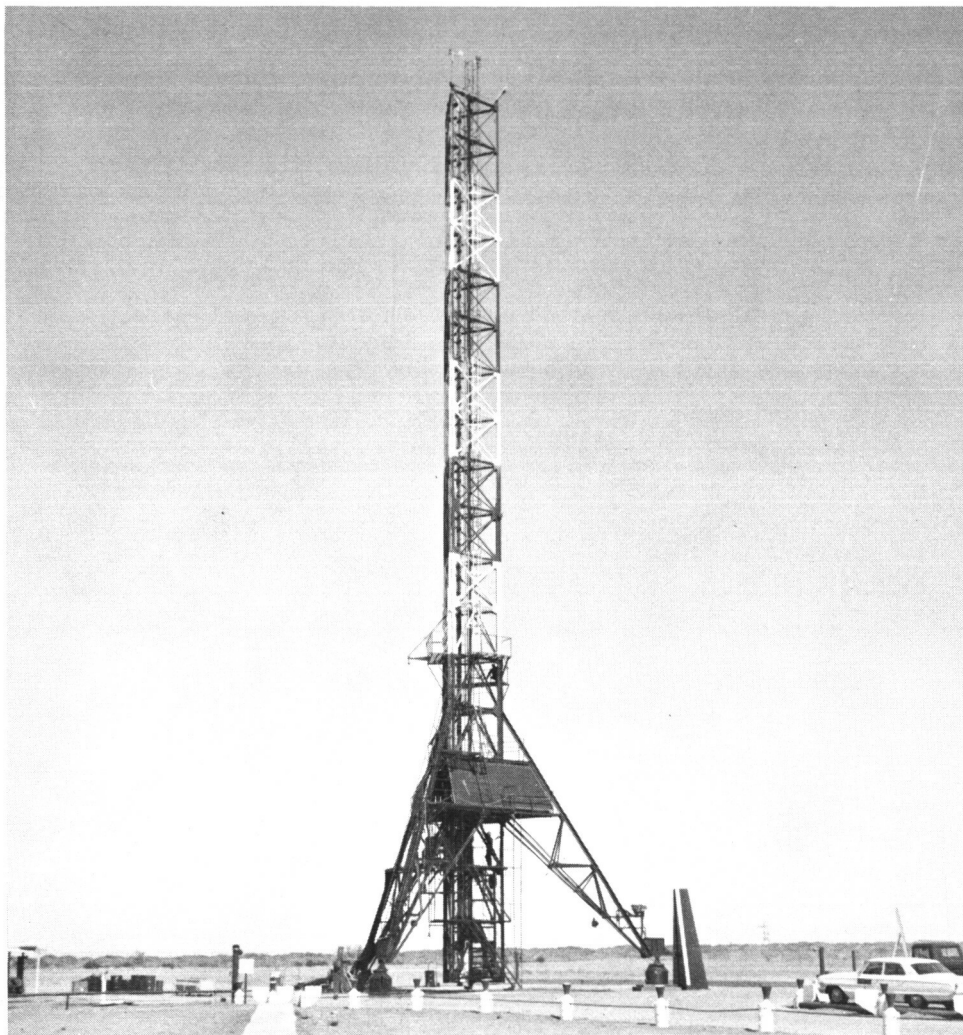


Figure 4. Launch Tower, White Sands Missile Range

More detailed information on each configuration, hardware and launch facilities is provided in Reference 1.

CHRONOLOGY

Twenty-eight Aerobee rockets were launched during 1964. Four Aerobee 150 A's and one Aerobee 300 A were launched from Wallops Island while 19 Aerobee 150's were launched from White Sands. Three Aerobee 150's and one Aerobee 300 were launched from the Churchill Research Range. NASA Flight 4.124 UA at Churchill was only a partial success while three consecutive flights from White Sands, NASA Flights 4.81 GG, 4.86 NA and 4.113 GA-GI were unsuccessful. Two of the failures were characterized by aerodynamic instabilities and one by a propulsion system failure.

Following investigation of the unrelated failures, significant remedial measures were instituted. Of the twenty-one subsequent firings, all rockets were completely or partially successful.

Twenty-one recovery systems were flown, of which two failed; however one of these recovery failures was in an attempt to recover an Aerobee 150 A sustainer with a new technique. Additionally one flight (NASA 4.67 NP) was recovered via an inflatable paraglider included in the payload section of the rocket.

Eight despin systems were flown: 5 gas and 3 yo-yo type. Of these, all the gas systems functioned well. One yo-yo despin system failed to function properly.

Ten rockets used ogive nose cones and the other eighteen used cone cylinder nose cones. Of the three unsatisfactory flights discussed for the year, two used cone cylinder nose cones. Two used a fiberglass ogive nose.

The fold-out cross reference index (Appendix A) can be useful in comparing the following flight descriptions for each flight with overall descriptive data for the year.

The following Aerobee rockets were launched during 1964:

<u>Flight Number</u>	<u>Launched From</u>	<u>Date of Launch</u>
4.88 GT	WSMR	1-28-64
6.09 GA	WI	1-29-64
4.124 UA	FC	2-27-64
4.15 GG	WSMR	4-3-64
4.81 GG	WSMR	4-9-64
4.86 NA	WSMR	4-14-64
4.113 GA-GI	WSMR	4-21-64
4.67 NP	WSMR	6-10-64
4.107 GE	FC	7-23-64
4.108 GE	FC	7-25-64

<u>Flight Number</u>	<u>Launched From</u>	<u>Date of Launch</u>
6.10 GA	FC	7-28-64
4.82 GG	WSMR	8-11-64
4.126 GG	WSMR	8-22-64
4.122 CG	WSMR	8-29-64
4.55 UG	WI	9-2-64
4.115 NA	WI	9-18-64
4.13 GP-GT	WI	9-27-64
4.120 CG	WSMR	10-1-64
4.123 CG	WSMR	10-27-64
4.116 GS	WSMR	10-30-64
4.52 UG	WSMR	11-3-64
4.109 GG	WSMR	11-7-64
4.110 GG	WSMR	11-14-64
4.118 NA	WSMR	11-16-64
4.45 GA	WI	11-16-64
4.83 GA	WSMR	11-28-64
4.132 GA-GI	WSMR	12-16-64
4.125 UA	WSMR	12-17-64

NASA Flight 4.88 GT

NASA Flight 4.88 GT, the first Aerobee firing in 1964, was launched successfully from the White Sands Missile Range (WSMR) on January 28, 1964. The rocket attained a peak altitude of 123.7 statute miles. The vehicle and all instrumentation performed as expected and good attitude control was indicated. The primary objective of the flight was to provide a thorough test of the currently used inertial attitude control system (IACS) with an improved inertial reference system. Other intended experimental objectives included:

- (1) Observance of performance of two roll-stabilized platforms
- (2) Observance of drift of platform mounted gyros during flight
- (3) Observance of maneuver accuracy
- (4) Observance of general control characteristics

During burning, and prior to 31 seconds, large and frequent center of motion shifts and large transient frequency responses were indicated. These frequencies were a mixture of vehicle roll rate and transient pitch responses resulting perhaps from tower exit, booster burnout and separation, and wind shears. At pitch-roll resonance large transient disturbances of short duration were observed; these were followed by motions basically at the pitch frequency. This indicates the presence of a large transient disturbance at resonance caused by rapid trim changes near resonance. Thrust chamber misalignments which were not measured during rocket build-up are a possible contributing cause of the trim changes. There was no evidence of pitch-roll lock-in.

The two roll-stabilized gyro platforms functioned well and succeeded in eliminating large gyro spin drifts, but the accuracy in performance of large maneuvers was less than desired. Aspect instrumentation in the payload included a Ball Brothers Sun Tracker, two Adcole wide angle sun sensors, a Whittaker aspect gyro, and two cameras; good data was received from all but the sun trackers yaw axis output.

The recovery system shown in Figure 5 was used on this flight and functioned as expected; recovery was effected immediately after impact and the payload was in excellent condition. Figure 6 provides an excellent view of the lift off.

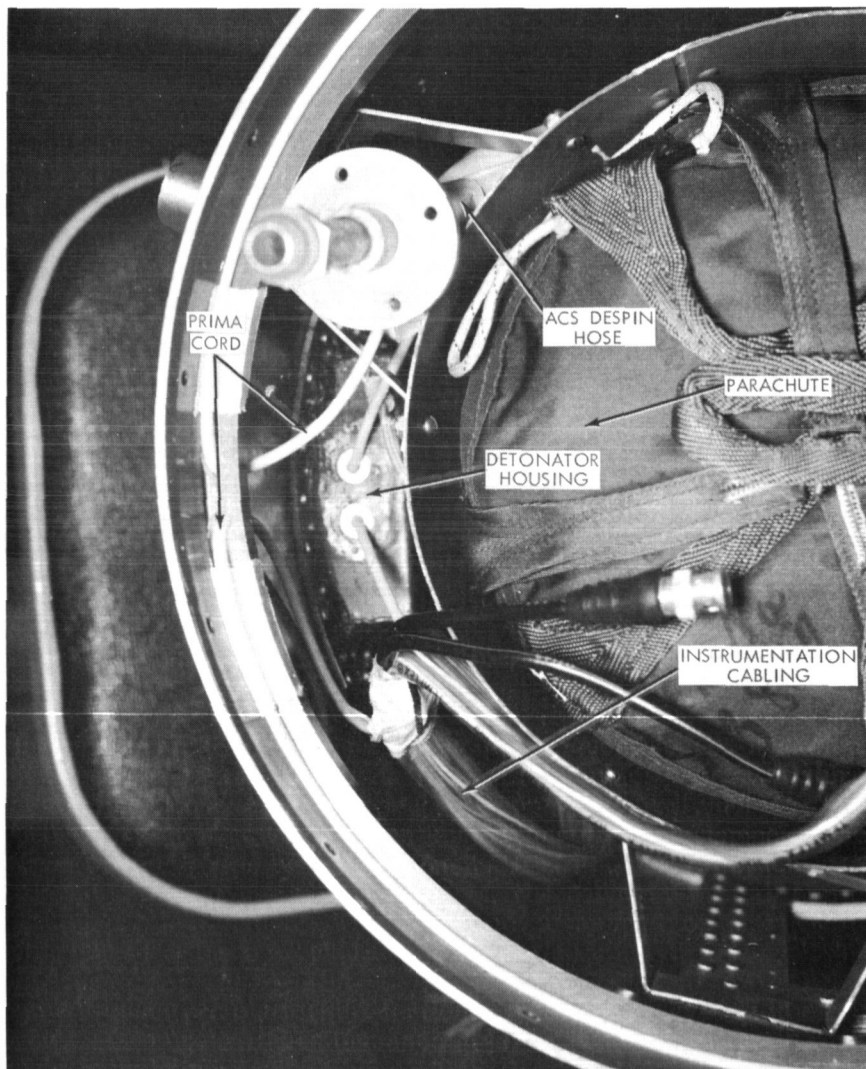


Figure 5. Recovery System Flown NASA 4.88 GT

The performance and configuration of NASA flight 4.88 GT is somewhat typical of NASA Aerobees launched from WSMR. Therefore Figures 7a through 7c are presented to give general flight performance characteristics. Figure 7d plots oxidizer tank pressure indicating a decrease in pressure as the ACS uses the residual pressure for maneuvers.

Figure 8 gives payload dimensions and characteristics of this flight.

NASA Flight 6.09 GA

NASA rocket 6.09 GA, an Aerobee 300 A, was launched successfully from Wallops Island (WI) on January 29; the rocket attained an altitude of 192.3 statute miles, approximately 4% lower than predicted.

The scientific payload for this flight was contained in an ejectable cylinder. The cylinder was housed in a 6.5 inch diameter, clamshell cone cylinder nose cone and was successfully ejected at T+87 seconds. Experimental objectives included:

- (1) Simultaneous measurement of electron neutral particle temperatures in the 120-360 km region
- (2) Measurement of ion and neutral particle density
- (3) Measurement of acceleration in 3 axes
- (4) Testing of repellent grid to be used on the S-6 satellite

Measurement of booster chamber pressure was accomplished during flight (see Figure 9); unfortunately booster wall temperatures could not be obtained due to a lag in the response time, coupled with a later shorting in the temperature sensor. Figure 10 shows the booster which is marked to indicate the position of one of the temperature sensors. Figure 11 shows booster acceleration from time zero to booster burnout.

Good 3 axis accelerometer data and chamber pressure data were received (Figures 12 and 13). Figure 14 gives payload dimensions and characteristics of this rocket and its flight.

NASA Flight 4.124 UA

NASA rocket 4.124 UA was launched at night from Fort Churchill (FC) on February 27. An excellent picture of tower exit observed that night is shown in Figure 15. The primary purpose of this flight was to obtain spectral emission data in the ultraviolet region of the upper atmosphere during an aurora. Spectrophotometric instrumentation was carried on board to measure these spectral features (Figure 16).

The vehicle performed normally during the boost phase; however the rocket failed to attain the predicted 157 statute miles apogee. Peak altitude was only 75% of predicted.

There were clear indications from telemetry and radar that pitch-roll lock-in occurred at resonance (approximately T+40 sec). Aerodynamic instabilities arising out of the coupling condition

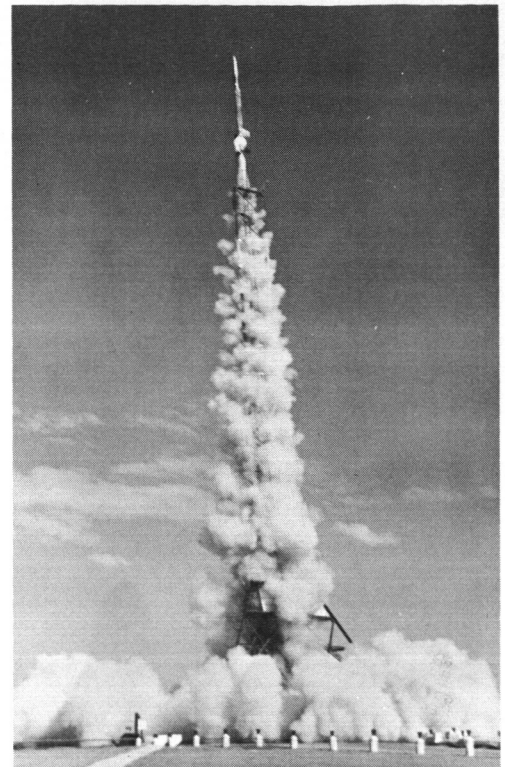


Figure 6. Lift Off Photo NASA 4.88 GT

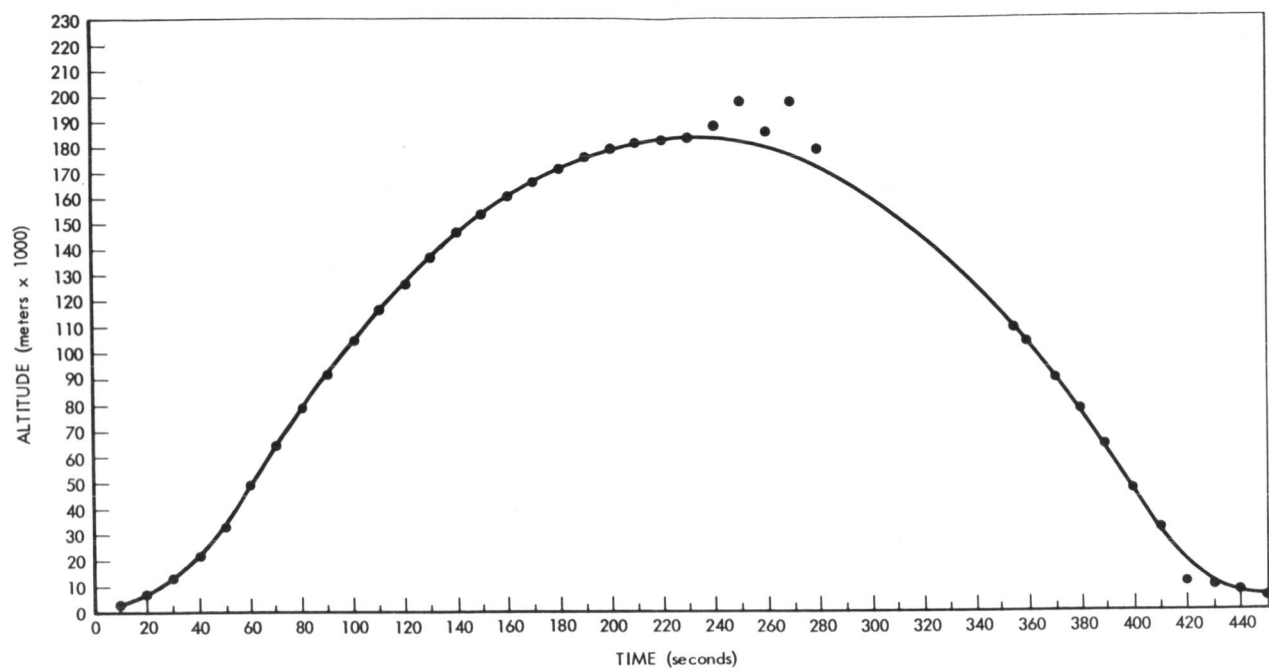


Figure 7a. Altitude vs Time (Flight 4.88 GT)

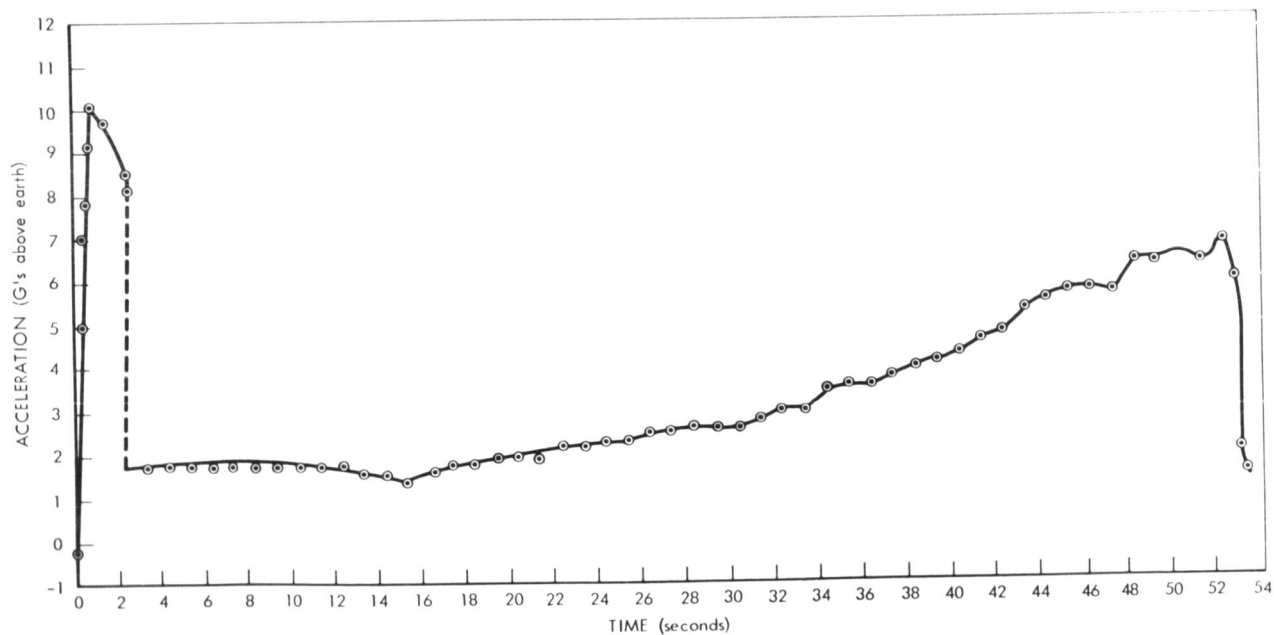


Figure 7b. Acceleration vs Time (Flight 4.88 GT)

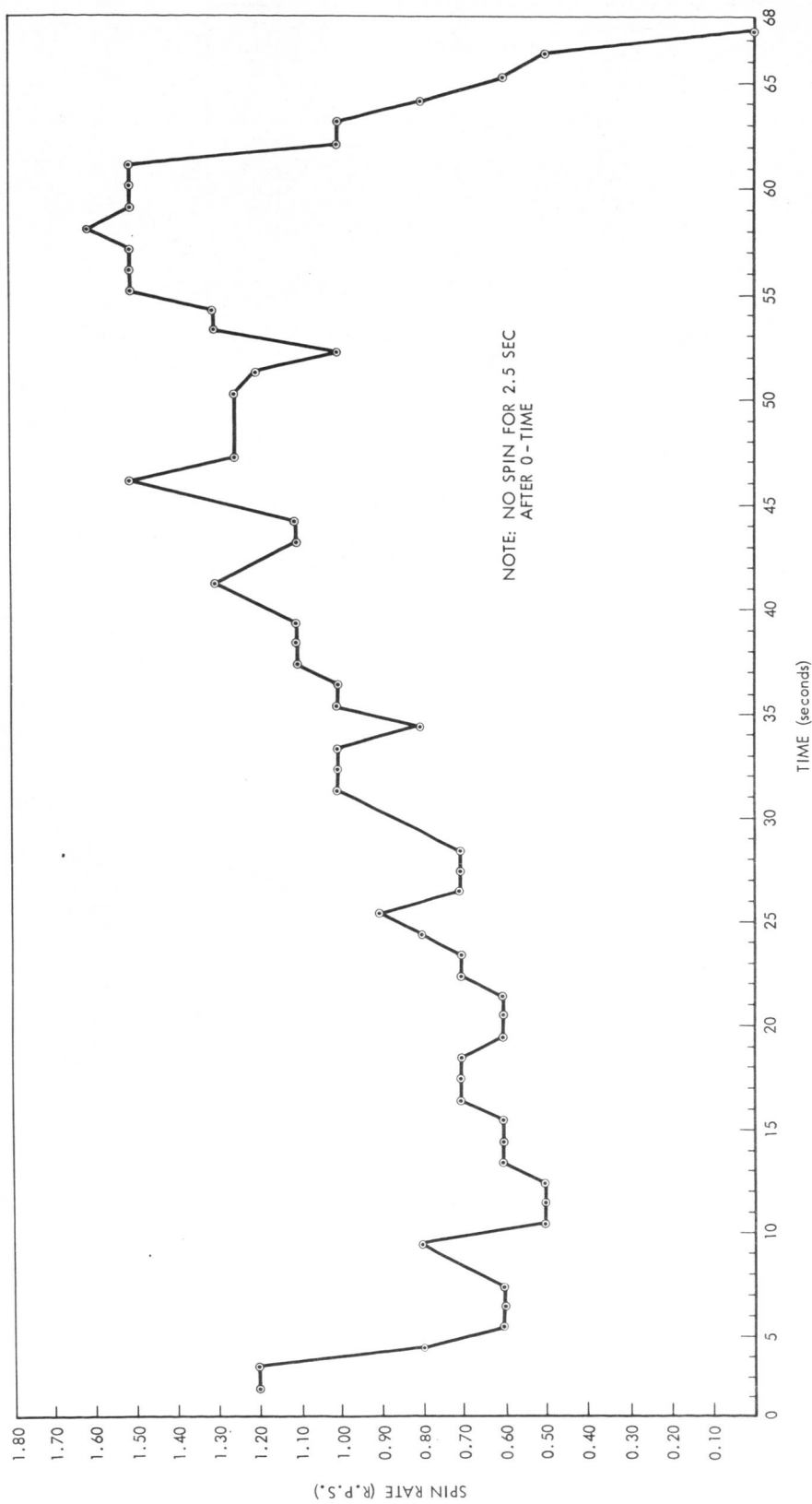


Figure 7c. Roll Rate vs Time (Flight 4.88 GT)

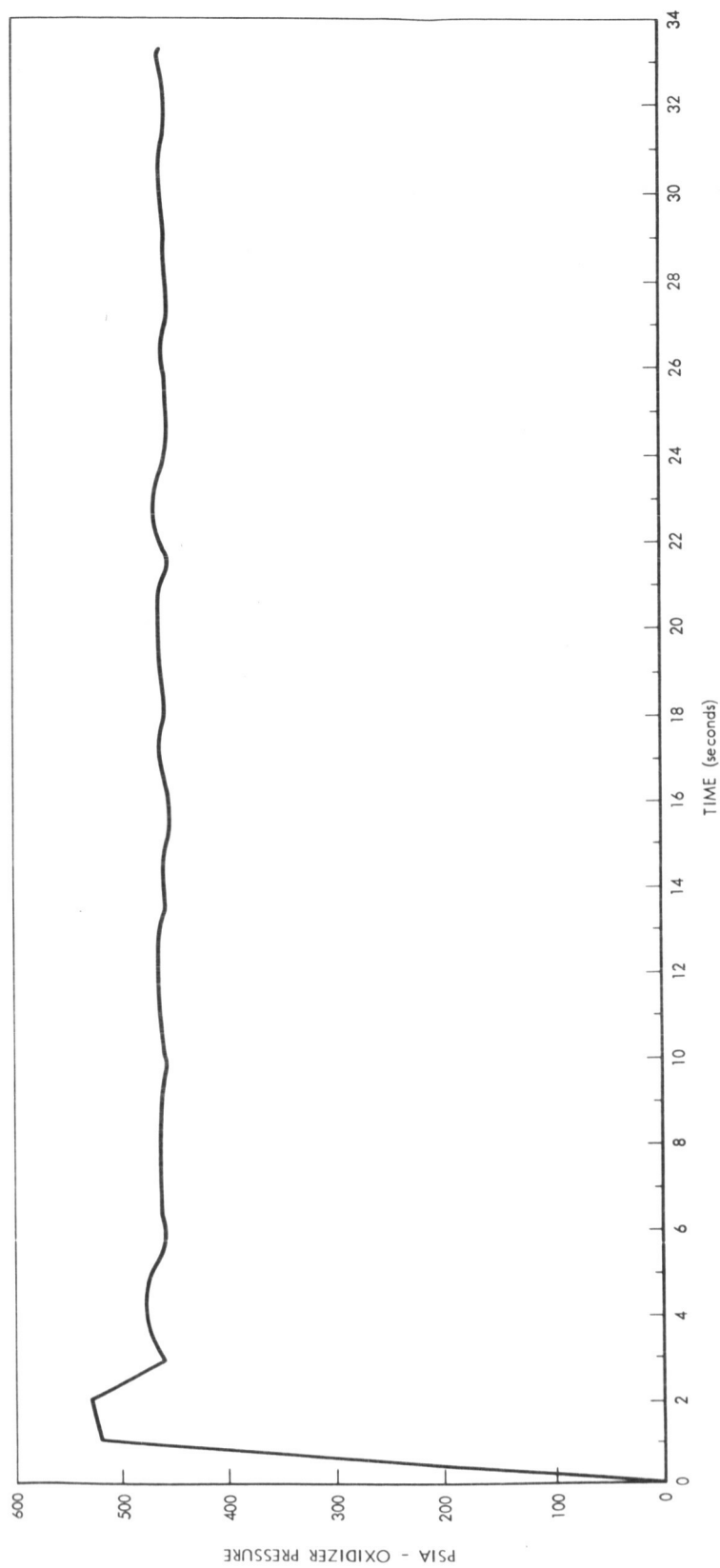


Figure 7d. Pox vs Time (Flight 4.88 GT) - 1 of 2

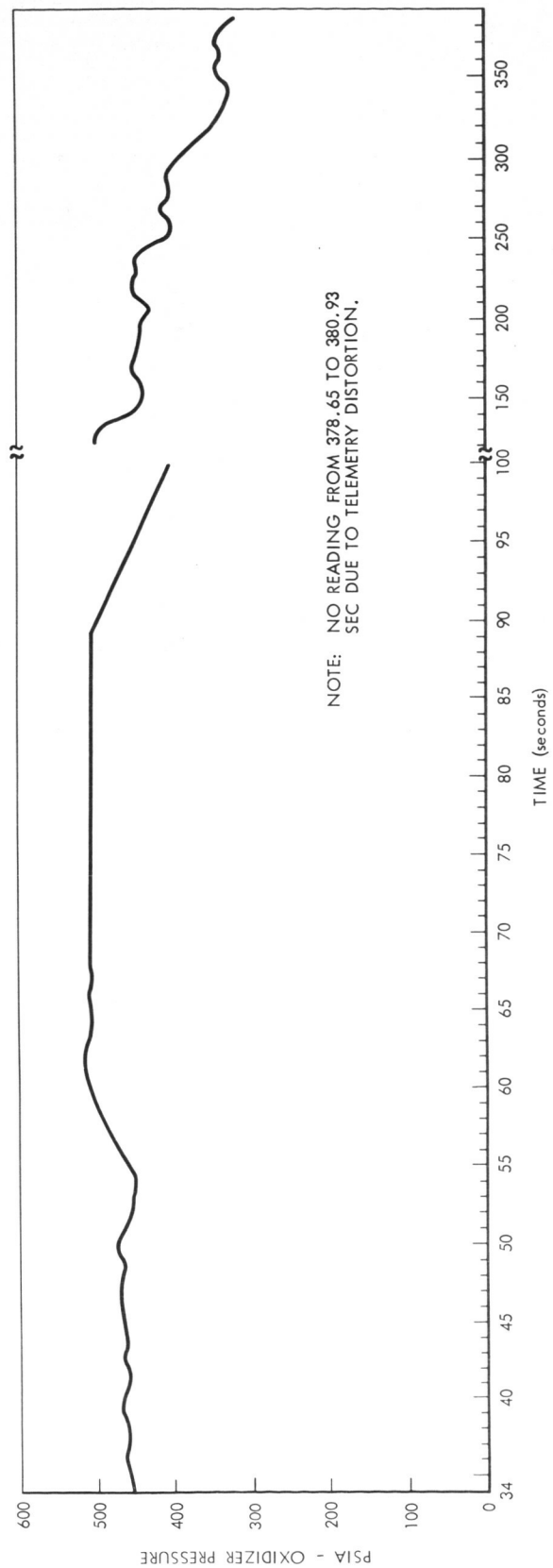
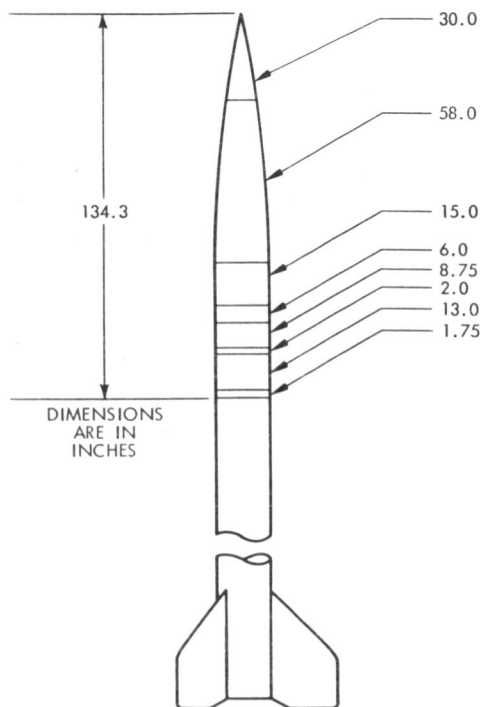


Figure 7d. Pox vs Time (Flight 4.88 GT) - 2 of 2



FLIGHT 4.88 GT	
FIRING DATE	28 JAN 1964
LAUNCH SITE	WSMR
PAYLOAD WT (LBS)	291.00
APOGEE (ST MI)	123.70
TIME TO APOGEE (SEC)	252.60
CENTER OF GRAVITY (CAL)	10.80
CENTER OF PRESSURE (CAL)	13.95
STATIC MARGIN (CAL)	3.15
RESTORING MOMENT (PER DEGREE)	-0.315
SUSTAINER BURNOUT TIME (SEC)	53.05
ROLL RATE AT BURNOUT (RPS)	1.45
EJECT TIP (SEC)	66.50
NO. OF JOINTS	8.00

Figure 8. Flight 4.88 GT - Dimensions and Flight Characteristics

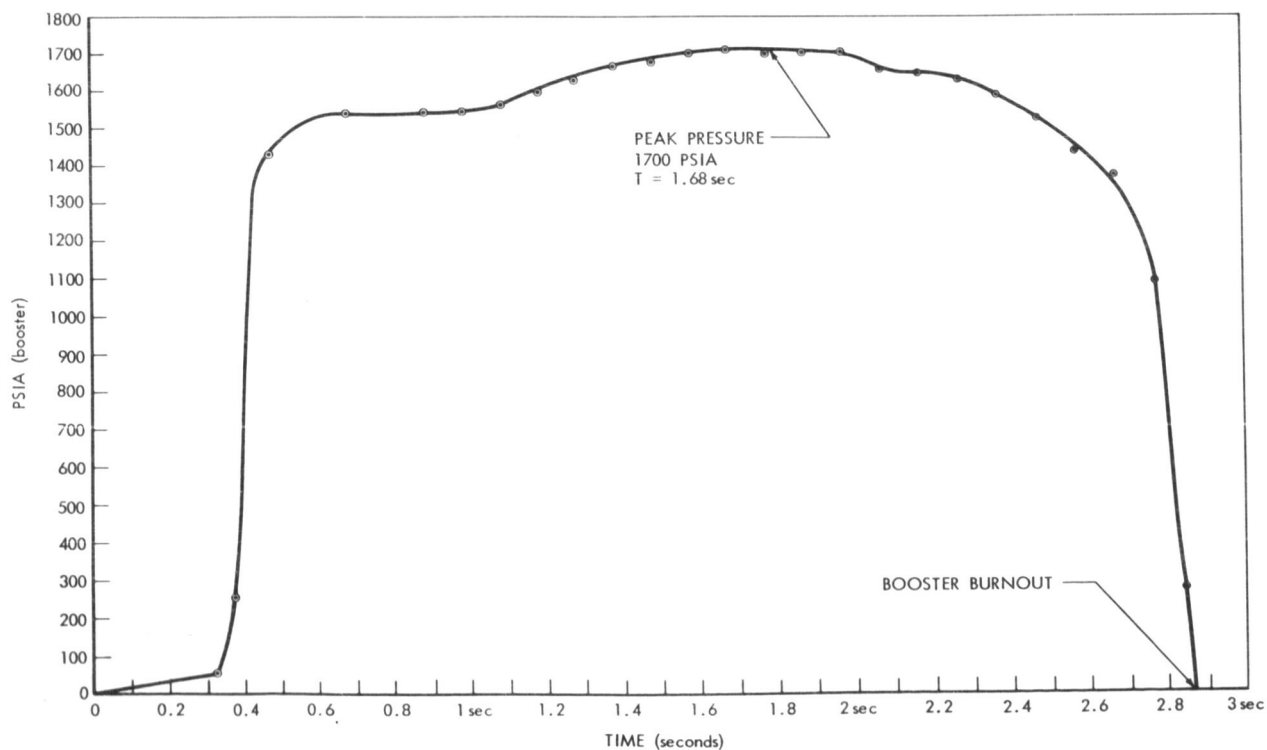


Figure 9. Booster Pressure (Flight 6.09 GA)



Figure 10. Flight 6.09GA - Booster Marked to Indicate Positions of Temperature Sensors

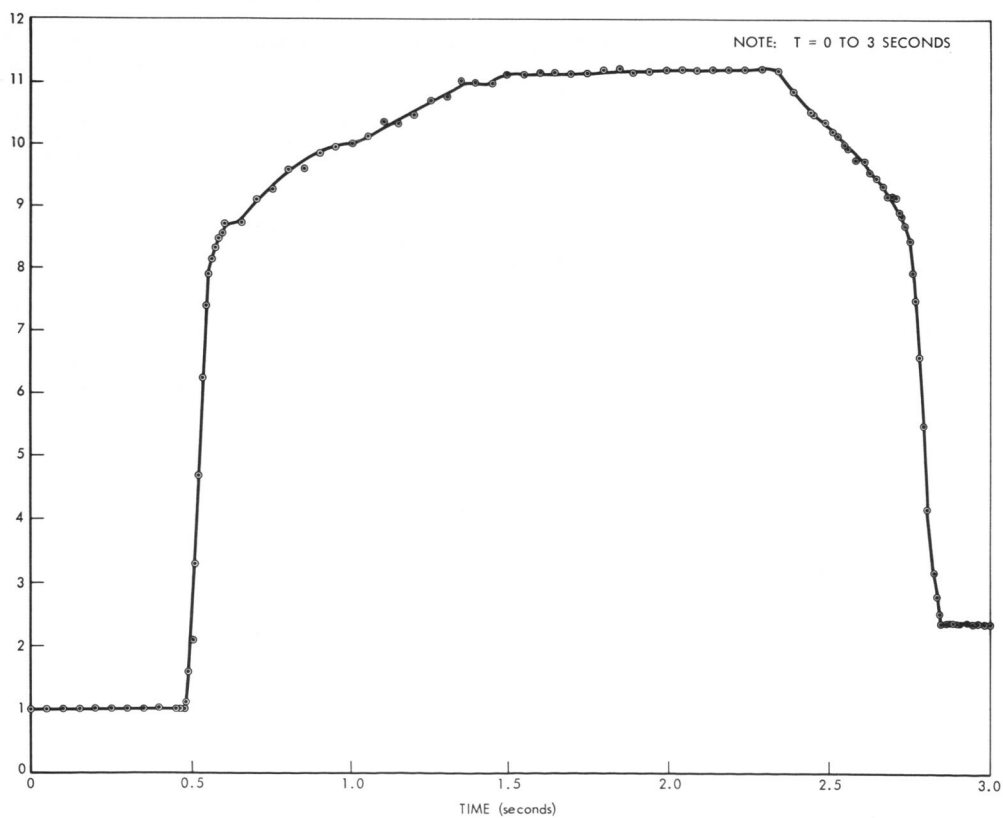


Figure 11. Flight 6.09GA - Booster Acceleration

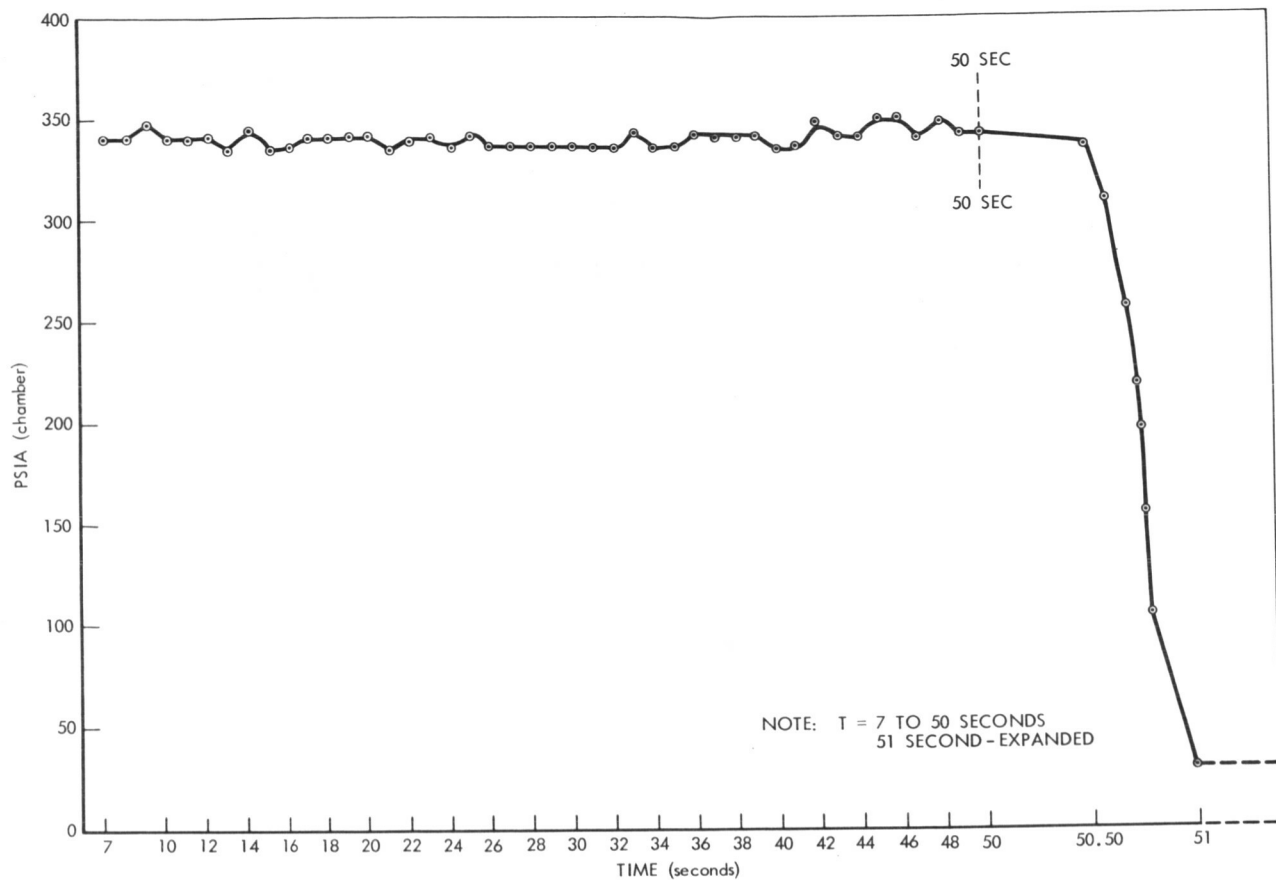


Figure 12. Flight 6.09GA - Sustainer Chamber Pressure

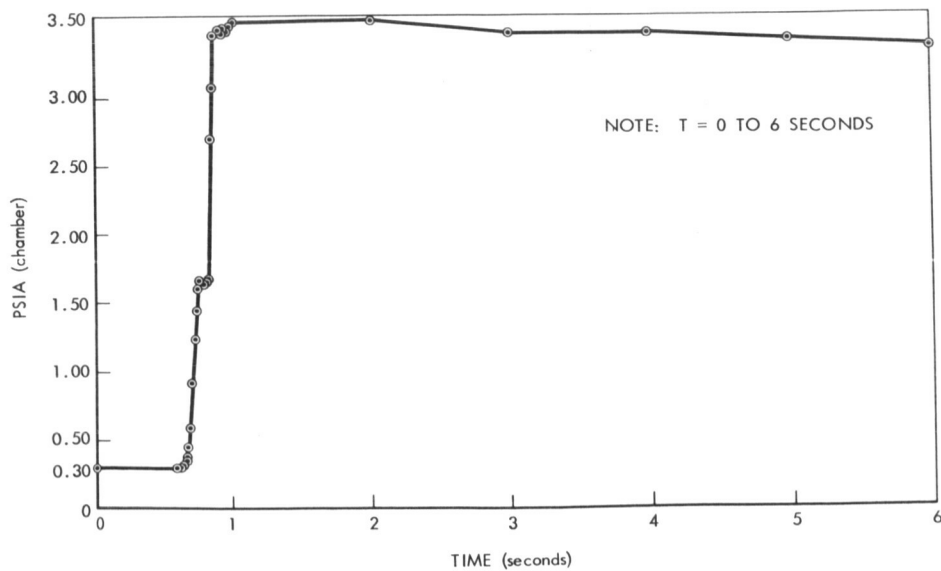


Figure 13. Flight 6.09GA - Sustainer Acceleration (1 of 3)

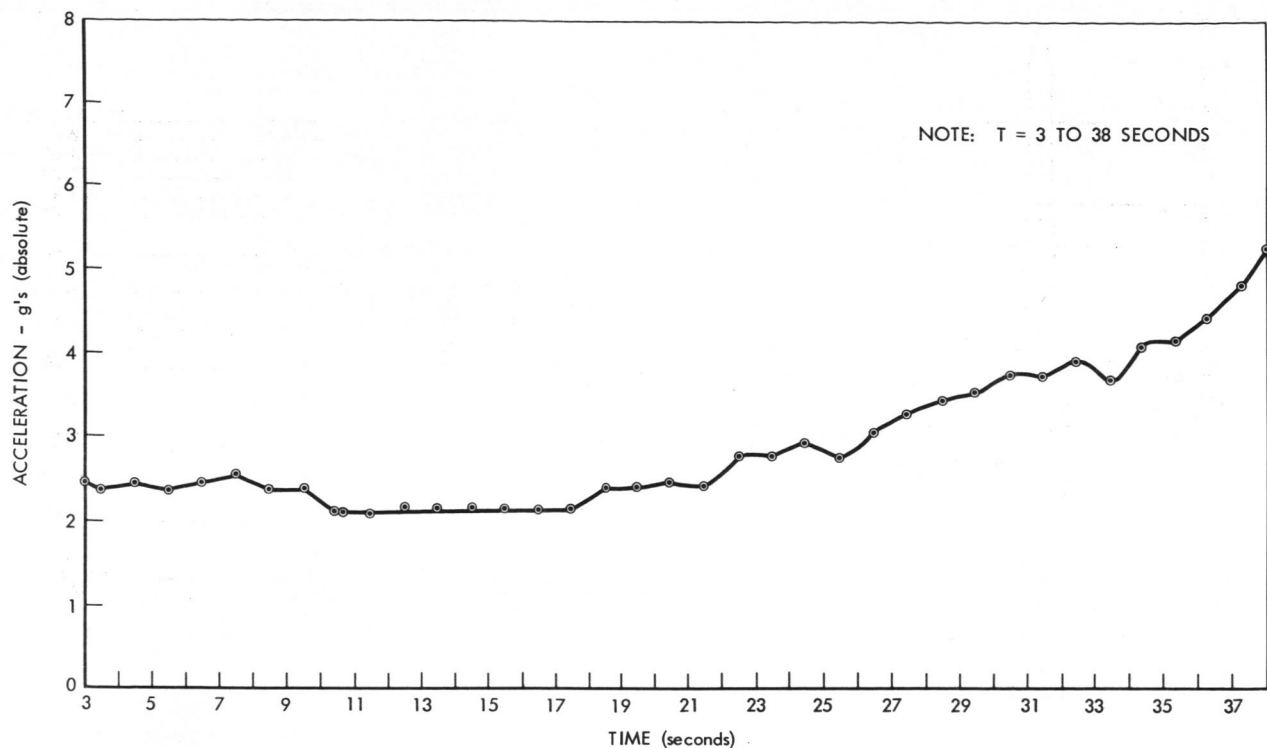


Figure 13. Flight 6.09 GA - Sustainer Acceleration (2 of 3)

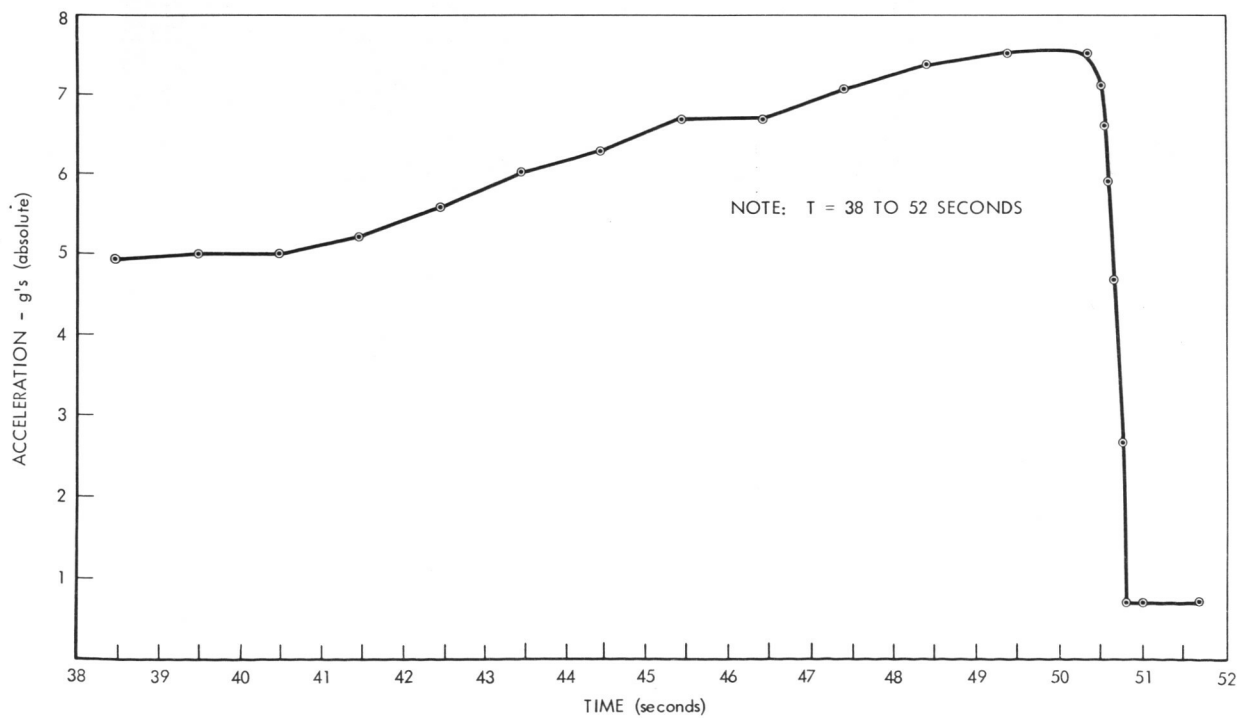
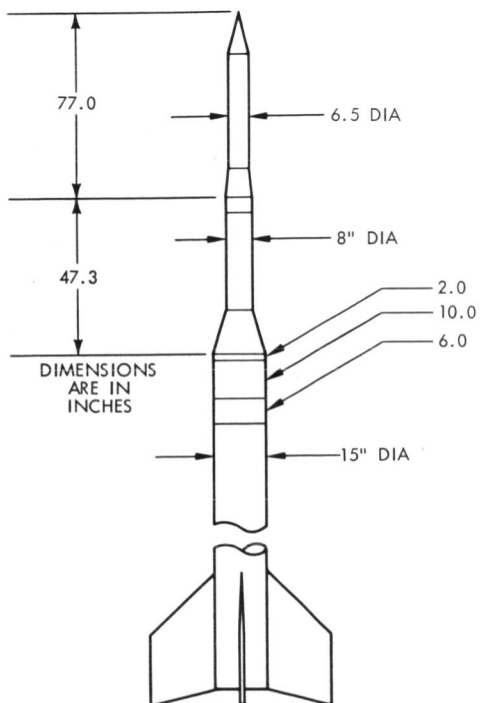


Figure 13. Flight 6.09 GA - Sustainer Acceleration (3 of 3)



FLIGHT 6.09GA

FIRING DATE	29 JAN 1964
LAUNCH SITE	WI
PAYLOAD WEIGHT, 2 ND STAGE (lbs)	273.05
APOGEE (statute miles)	192.30
TIME TO APOGEE (seconds)	300.20
CENTER OF GRAVITY, SUSTAINER BURNOUT	11.25
(calculated)	
CENTER OF PRESSURE, SUSTAINER BURNOUT	15.62
(calculated)	
STATIC MARGIN, SUSTAINER BURNOUT	4.37
(calculated)	
RESTORING MOMENT, SUSTAINER BURNOUT	-0.594
(per degree)	
CENTER OF GRAVITY, 3RD STAGE IGNITION	7.80
(calculated)	
CENTER OF PRESSURE, 3RD STAGE IGNITION	11.16
(calculated)	
STATIC MARGIN, 3RD STAGE IGNITION	3.36
(calculated)	
RESTORING MOMENT, 3RD STAGE IGNITION	-0.1208
(per degree)	
SUSTAINER BURNOUT (seconds)	50.80
THIRD STAGE BURNOUT (seconds)	53.80
ROLL RATE AT BURNOUT, SUSTAINER (rps)	2.70
ROLL RATE AT BURNOUT, 3RD STAGE (rps)	unknown
PROBE EJECT (seconds)	~97.00
NUMBER OF JOINTS	5.00
PAYLOAD WEIGHT, 3RD STAGE (lbs)	84.75

Figure 14. Flight 6.09GA - Dimensions and Flight Characteristics

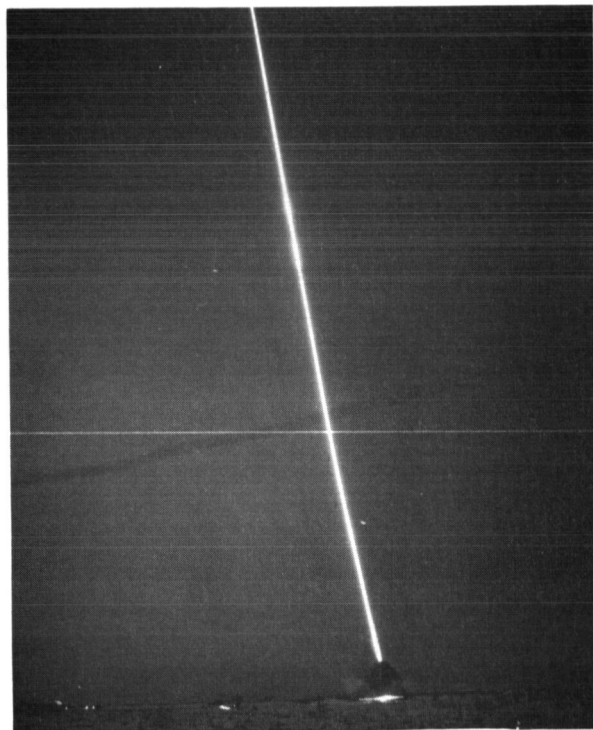


Figure 15. Flight 4.124UA - Night Lift Off
from Fort Churchill Range

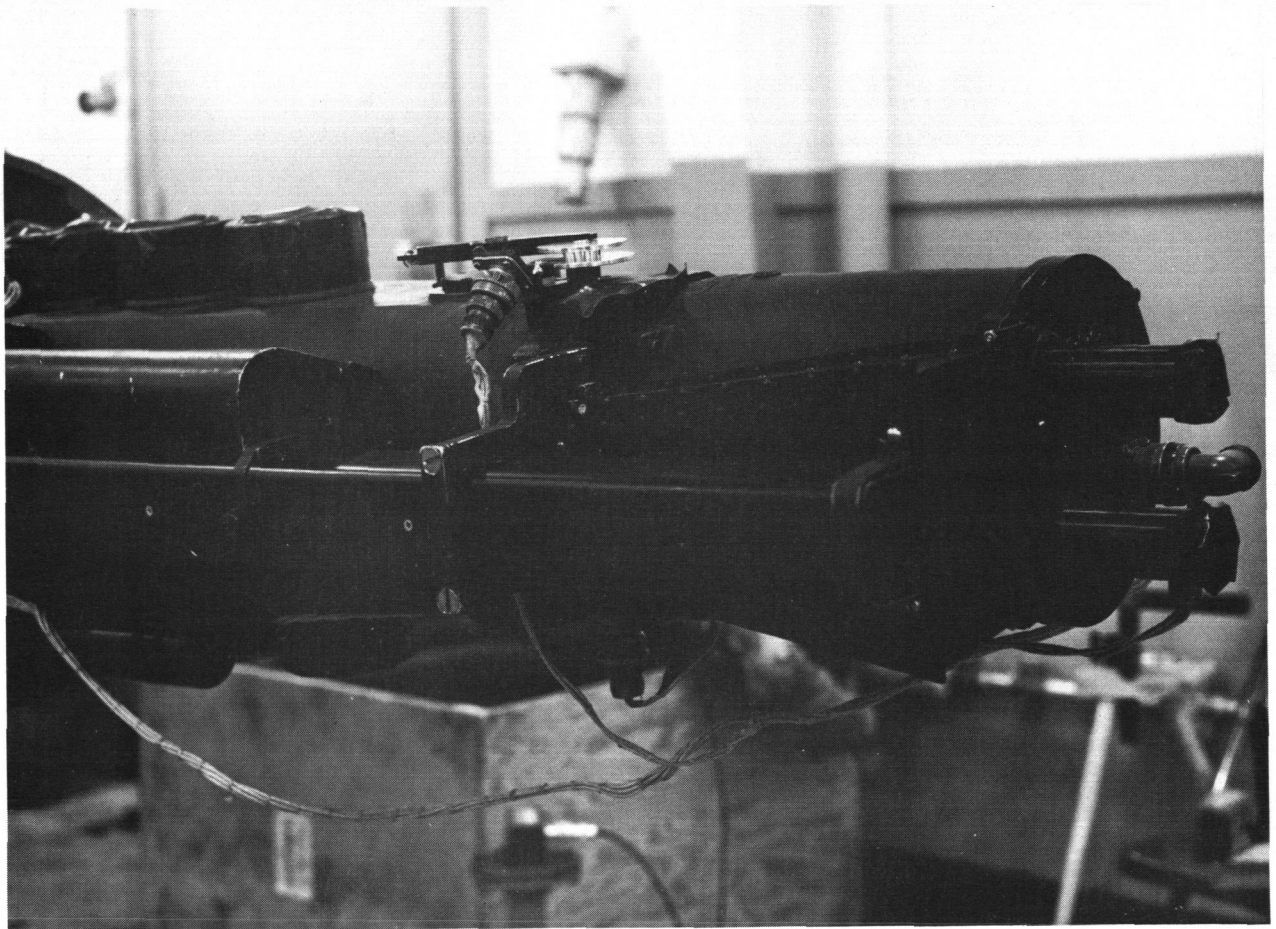


Figure 16. Flight 4.124UA - Spectrophotometric Instrumentation

caused the rocket to "cone" while precessing about its axis thus causing the degradation in rocket performance. An unexplained early tip ejection occurred at 59 seconds; this had no effect on vehicle performance.

Figure 17 shows the acceleration time history during the propulsion portion of flight. Figure 18 shows the thrust chamber pressure history for the same period. Both are as expected.

The actual roll rate is compared to the predicted roll history in Figure 19. Figure 20 compares degraded altitude and predicted trajectory performance. The flight is not considered a failure, however, since the vehicle did penetrate an auroral event and some experimental data were collected. Also, as we shall observe on two other flight analyses, 4.81 GG and 4.86 NA, the results of this flight did contribute to the establishment of later Aerobee improvements.

Figure 21 gives payload dimensions and characteristics of this rocket and its flight.

NASA Flight 4.15 GG

NASA Aerobee 4.15 GG was launched from WSMR on 3 April. The primary objectives were to obtain spectra data on the nebulosities of certain star fields. One camera and spectrograph were pointed out the nose of the nose cone cylinder and the other pair were pointed to look out the side of the cylinder. Prior to launching, the tail can had been drilled with nine 3/4 inch holes, to permit outgassing.

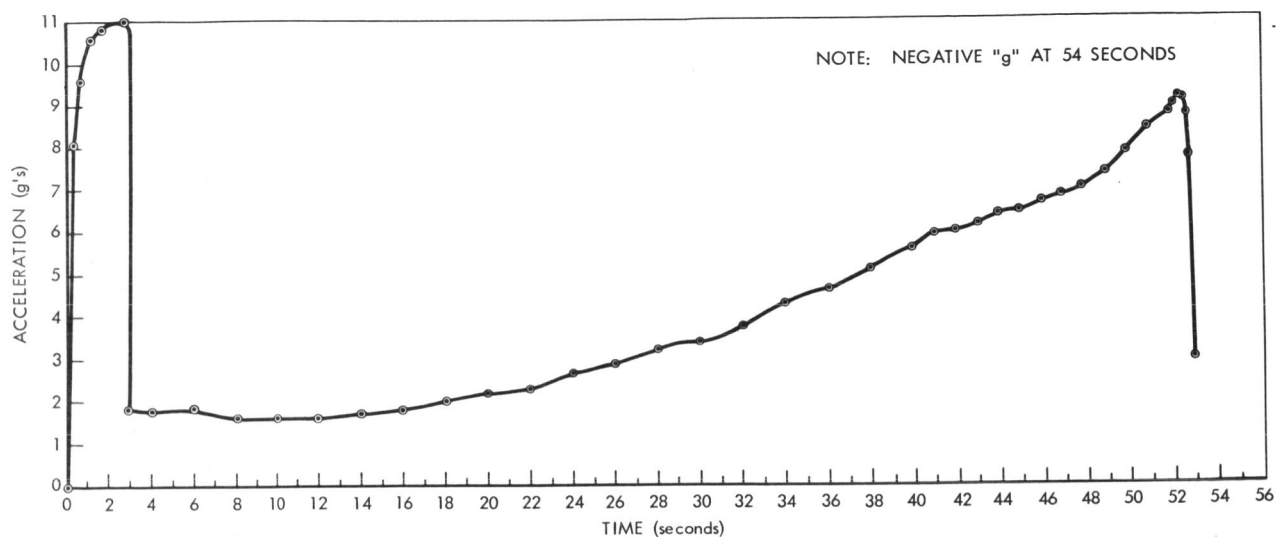


Figure 17. Flight 4.124UA - Acceleration vs Time

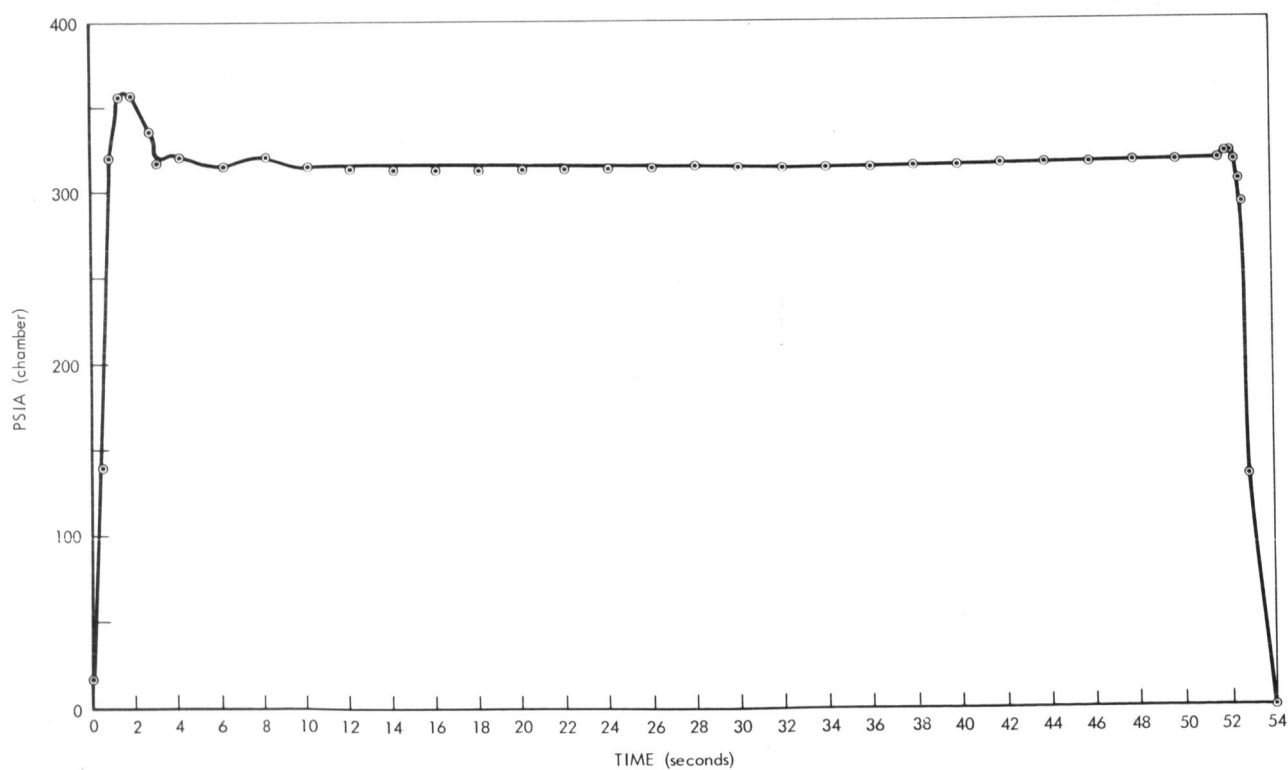


Figure 18. Flight 4.124UA - Chamber Pressure vs Time

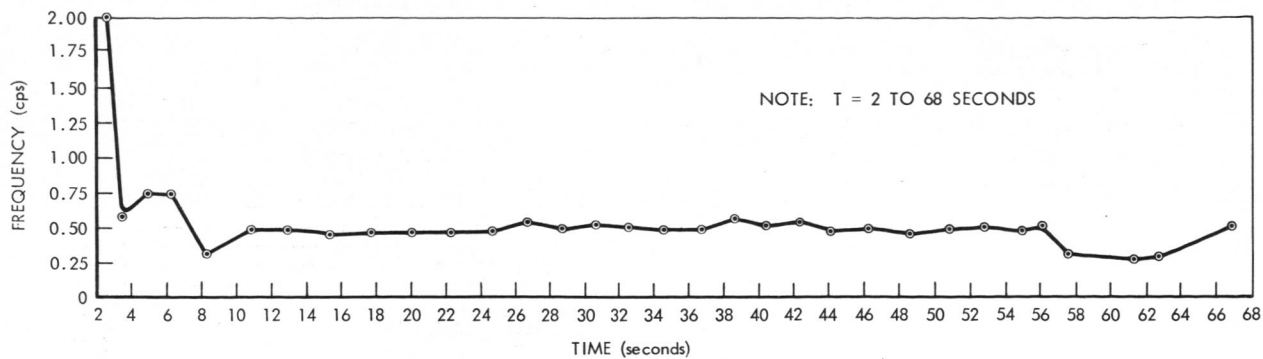


Figure 19. Flight 4.124UA - Roll Rate vs Time

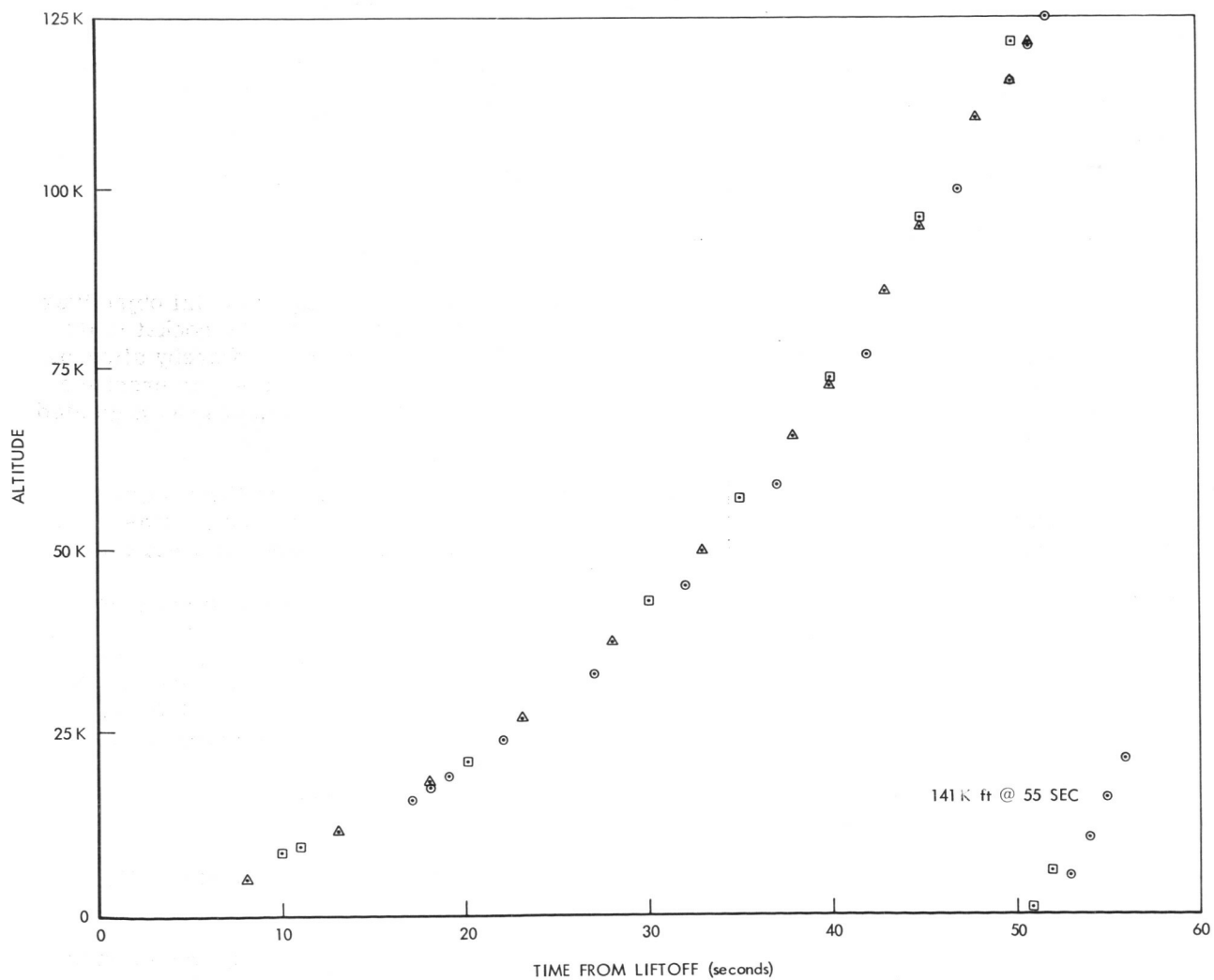


Figure 20. Flight 4.124UA - Altitude vs Time

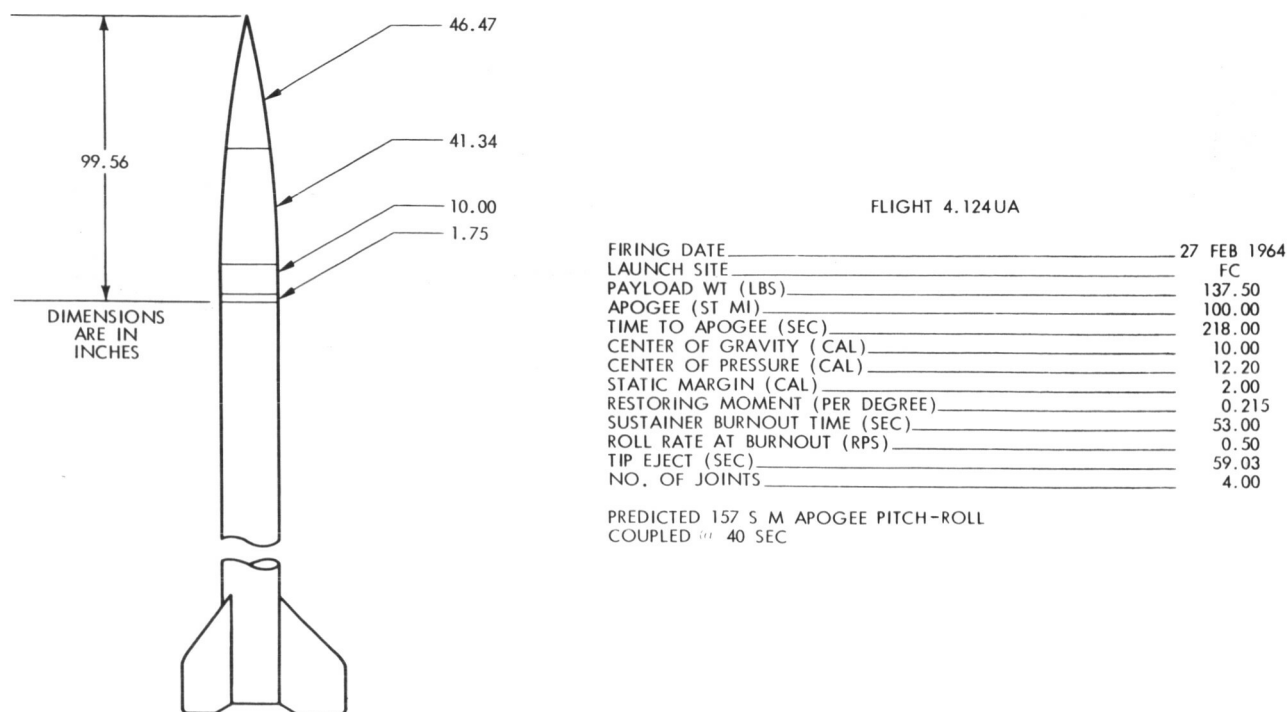


Figure 21. Flight 4.124 UA - Dimensions and Flight Characteristics

The rocket and instrumentation performed satisfactorily; however the experimental objectives were not attained because the Attitude Control System (ACS) was unable to erect the rocket to the gyros. This resulted from the failure of the fuel shut-off valve to seat properly, thereby allowing residual helium to "blow-out" the thrust chamber. There was not enough helium left to erect the vehicle to the pitch gyro. The shut-off valve failure was not immediately detected as the regulated helium pressure gauge did not function.

Two subsequent flights, 4.81 GG and 4.86 NA resulted in failures; because of the similar vehicle configuration and the availability of ACS gyro outputs, the 4.15 GG flight motion was analyzed for comparison with these two failures. A detailed analysis is presented in reference 2.

There were some transient responses indicated during the first seconds of flight; but they were probably due to tower exit disturbances, booster burnout and separation, and wind shears. These transients were not considered abnormal. Sizeable shifts in the center of motion occurred early in flight and this made it difficult to determine the exact nature of the rocket motion. The frequencies observed seemed to be composed of a mixture of transient oscillations in pitch frequency (Figure 22) and fairly steady oscillations in roll rate. Figure 22 also plots yaw frequency data during propulsion. Thrust chamber misalignments are thought to be a possible factor responsible for roll rate oscillations observed later; this is not observable in the chamber pressure trace which is steady and as expected (Figure 23).

Other data included for this flight are Wind Velocities and Flight Azimuth vs Altitude (Figure 24a) and Acceleration vs Time (Figure 24b).

The rocket satisfactorily achieved an apogee of 118.6 statute miles; the nose tip was ejected at 85 seconds as planned. The recovery system functioned satisfactorily, and the payload was successfully recovered in good condition.

Figure 25 gives payload dimensions and characteristics of the rocket and its flight.

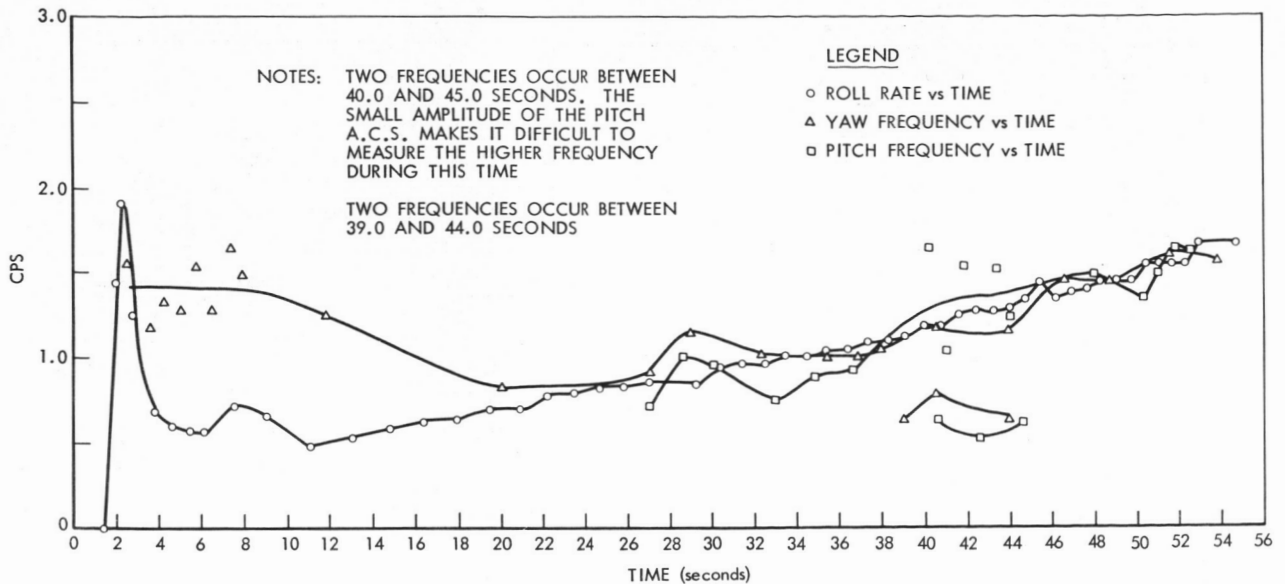


Figure 22. Flight 4.15 GG - Pitch, Yaw and Roll Rate vs Time

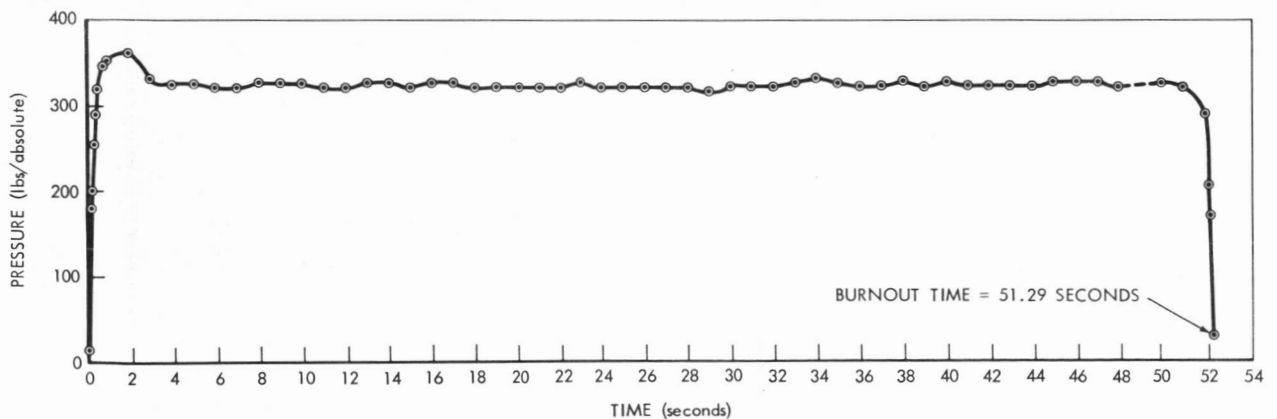


Figure 23. Flight 4.15 GG - Chamber Pressure vs Time

NASA Flights 4.81 GG and 4.86 NA

NASA flights 4.81 GG and 4.86 NA resulted in two consecutive failures. The cause of failure in each case, has been attributed to bi-modal instability arising from frequencies that preceded pitch-roll lock-in; it is theorized that the large angles of attack resulting from the bi-modal instabilities permitted the lock-in to occur. Facts concerning each flight are described in the following paragraphs; flight details, analyses, and conclusions are the subject of reference 2 currently in preparation. The following are general comments about each flight and a summary of the conclusions and remedial actions instituted.

NASA Flight 4.81 GG—NASA Aerobee 4.81 GG was launched in 9 April. This flight resulted in the first vehicle failure of the year. Similar in configuration to NASA 4.15 GG, though longer, the payload housed two cameras and two spectrographs for obtaining data on the spectra of certain star field nebulosities. Rocket instrumentation included: a thrust chamber pressure gauge, accelerometer, helium gauge, and lateral and longitudinal magnetometers.

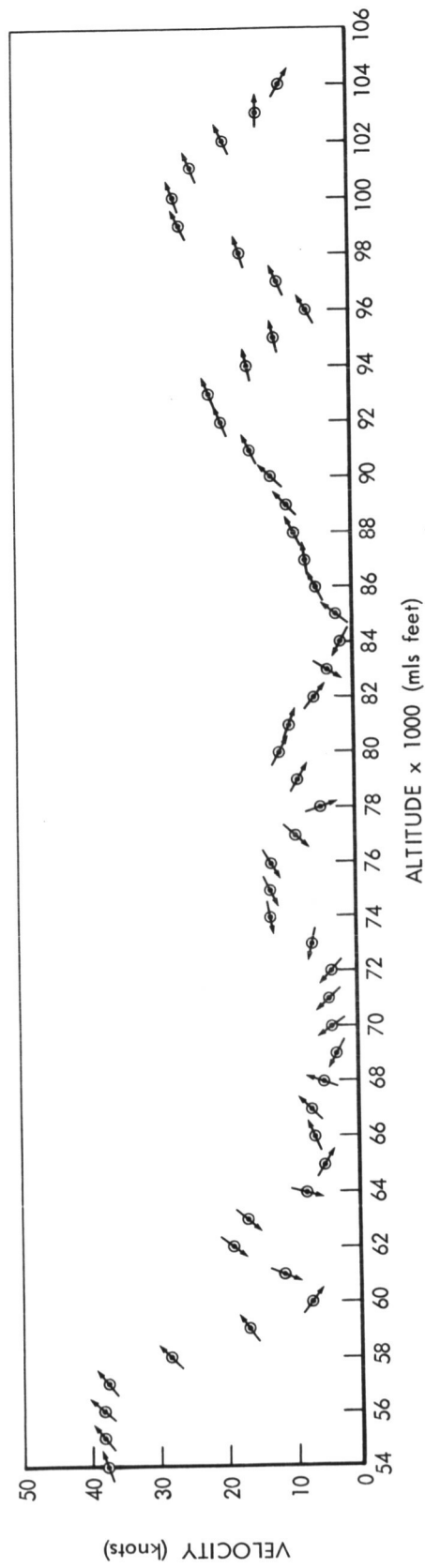
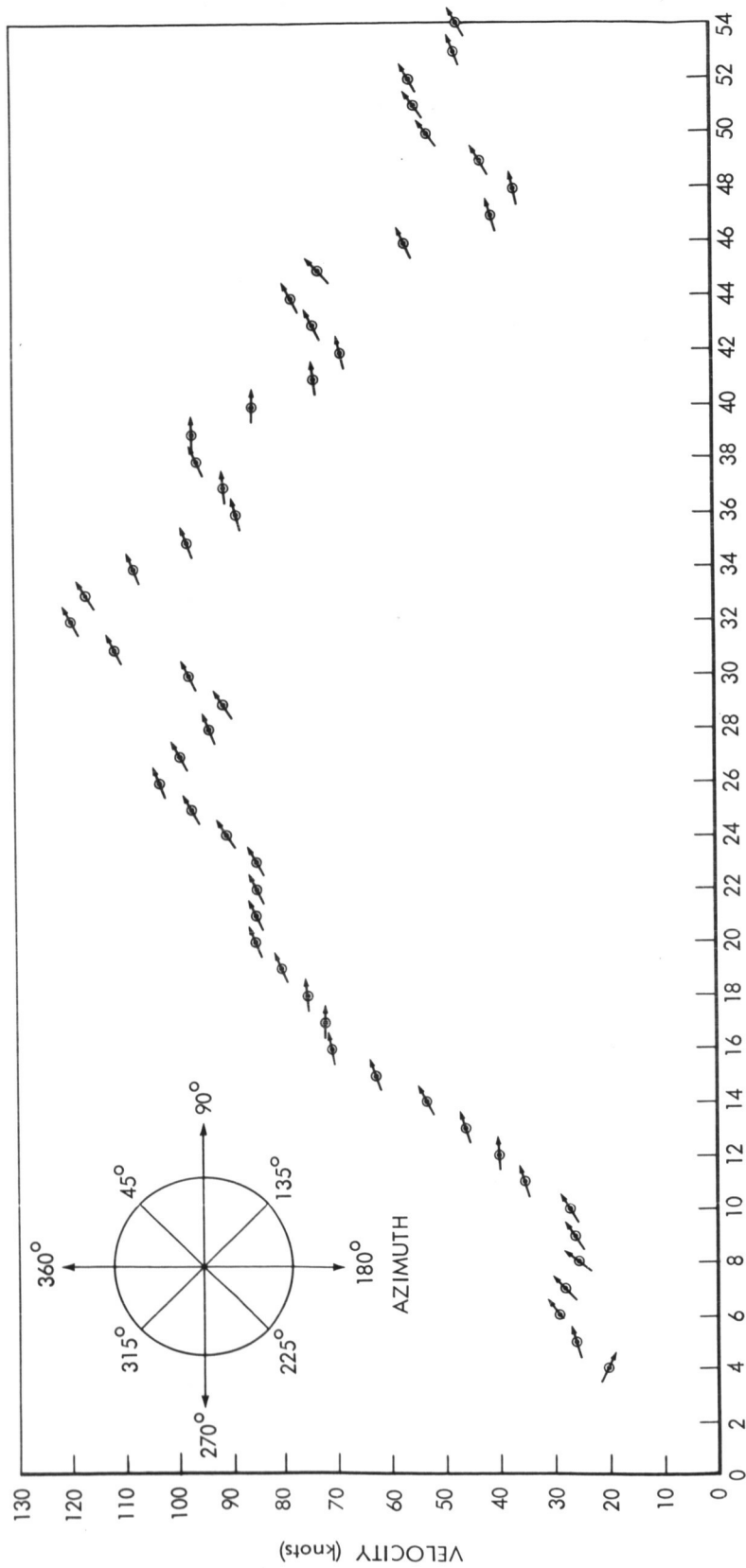


Figure 24a. Flight 4.15 GG - Wind Velocity and Azimuth vs Altitude

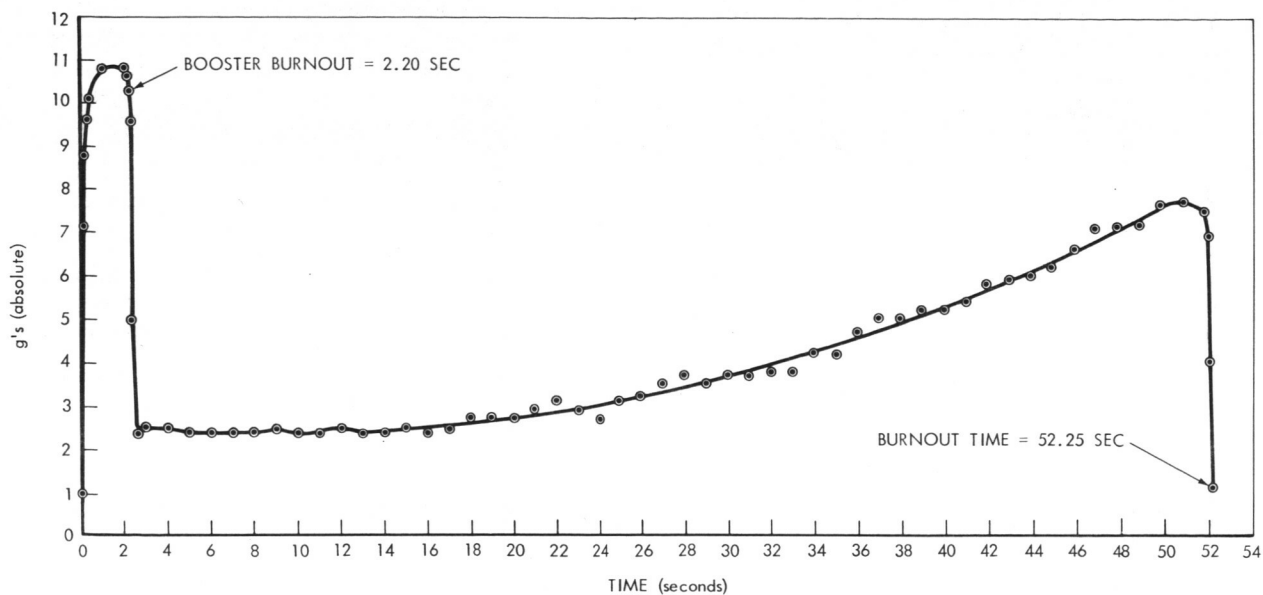
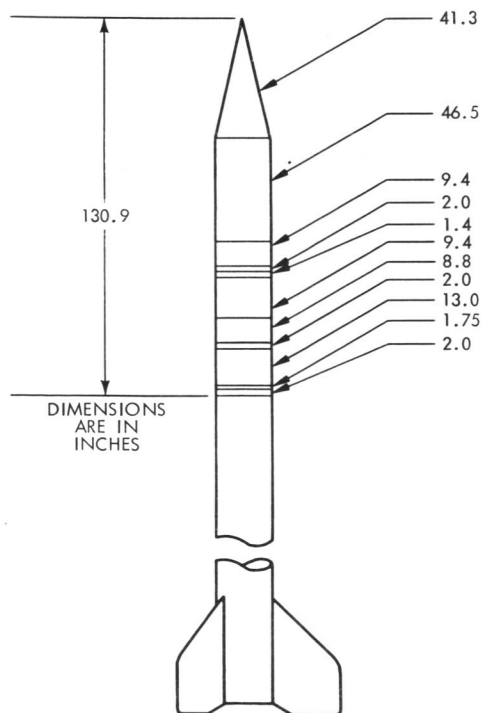


Figure 24b. Flight 4.15GG - Acceleration vs Time



FLIGHT 4.15GG

FIRING DATE	2 APR 1964
LAUNCH SITE	WSMR
PAYLOAD WT (LBS)	258.00
APOGEE (ST MI)	118.60
TIME TO APOGEE (SEC)	235.90
CENTER OF GRAVITY (CAL)	11.00
CENTER OF PRESSURE (CAL)	13.20
STATIC MARGIN (CAL)	2.20
RESTORING MOMENT (PER DEGREE)	-0.23
SUSTAINER BURNOUT TIME (SEC)	52.40
ROLL RATE AT BURNOUT (RPS)	1.55
TIP EJECT (SEC)	85.00
NO. OF JOINTS	11.00

Figure 25. Flight 4.15GG - Dimensions and Flight Characteristics

Vehicle motion appeared relatively steady until T+29 seconds. At this time half-amplitudes of motion about center grew to 2° by 32 seconds and to about 7° by 39 seconds. It is assumed that a low body bending frequency on the order of 1 cps (resulting perhaps from joint slippage) dynamically coupled with a pitching mode at 29 seconds to cause this large growth in amplitude. At 40 seconds the nosecone microswitch output indicated a premature tip eject and by 42 seconds the vehicle had "locked in." It is thought that the pitch-roll couple lock-in at 40 seconds resulted from the structural failure of the nose tip and was not a basic cause of flight anomalies. Static tests at GSFC have confirmed that larger than design angles of attack created overbearing aerodynamic loads on the tip eject mechanism.

Figure 26 shows a representative wind run taken shortly before the flight; there are no indications of large enough wind shears that could have predictably contributed to the failure.

Figure 27 plots roll rate and pitching frequency vs time. Figure 28 shows the thrust chamber pressure trace, which is as expected, and the acceleration time history. Burnout acceleration is lower than expected and the "dip" at 43 seconds indicates lock-in of the pitch and roll frequencies.

Although the rocket was a failure, the recovery system functioned properly, and the payload was recovered. Conclusions from analysis of flight data (p. 31) have resulted in improvements which will help avoid similar reoccurrences.

NASA Flight 4.86 NA—NASA flight 4.86 NA was launched on 14 April from WSMR. This flight resulted in the second consecutive Aerobee 150 failure and was similar to NASA 4.81 GG. In the early seconds of flight, no unusual motions were detected (Figure 29). However, as occurred on the 4.81 GG flight, amplitude of motion about the rocket's center began to increase subsequent to 32 seconds resulting in pitch-roll lock-in which occurred at 40 seconds. Figure 30 shows a useful roll rate comparison illustrating this behavior.

Erratic accelerations were indicated from T+42 seconds until T+48 seconds; figure 31 indicates this. Figure 32, thrust chamber pressure, exhibited no unusual characteristics. As for flight 4.81 GG, representative wind data is provided for this flight (See Figure 33). This data, however, did not provide any basis for assuming that significant wind shears contributed to the failure.

At T+61.5 seconds the forward 55 inches of the cone cylinder nose cone was ejected by timer command; no experimental objectives could be realized, however, since the ACS was unable to erect the vehicle to the gyros. The ACS had been programmed to yaw the rocket to the nadir soon after burnout, and then yaw it up to the zenith at apogee. On the descending leg of the trajectory, the rocket was to be turned downwards toward the horizon in the North and remain there until payload separation. An Ebert-Fastie optical spectrometer and three photometers were contained in the payload section; they were to measure the sun's ultraviolet light that is scattered by the earth's atmosphere as well as to correlate the fluctuation of this phenomena in the earth's magnetic field by using magnetometers. The recovery system functioned properly and the payload was successfully recovered.

Although an apogee of only 18 statute miles was obtained, vehicle performance instrumentation and ACS gyro data were very good and were used in the analyses to determine the causes of failure. The following lists the general physical and aerodynamic characteristics of the 4.81 GG and 4.86 GA failures:

- (1) The payloads used cone cylinder nose cones and were longer than most payloads flown up until that time.
- (2) There were an unusually large number of extensions.
- (3) Bi-modal frequencies were observed in pitch and roll prior to coupling and are theorized to have been responsible for causing pitch roll lock-in.
- (4) Pitch-roll coupling occurred at approximately T+40 seconds.
- (5) "Lock-in" occurred at pitch-roll resonance which resulted in a vehicle failure.

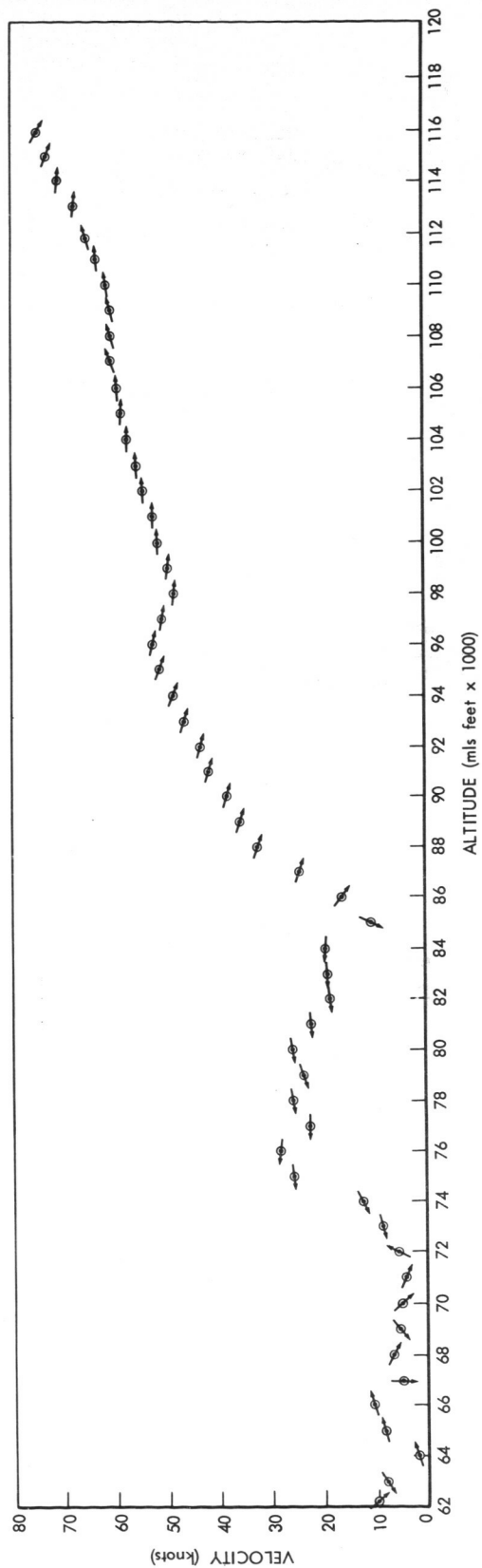
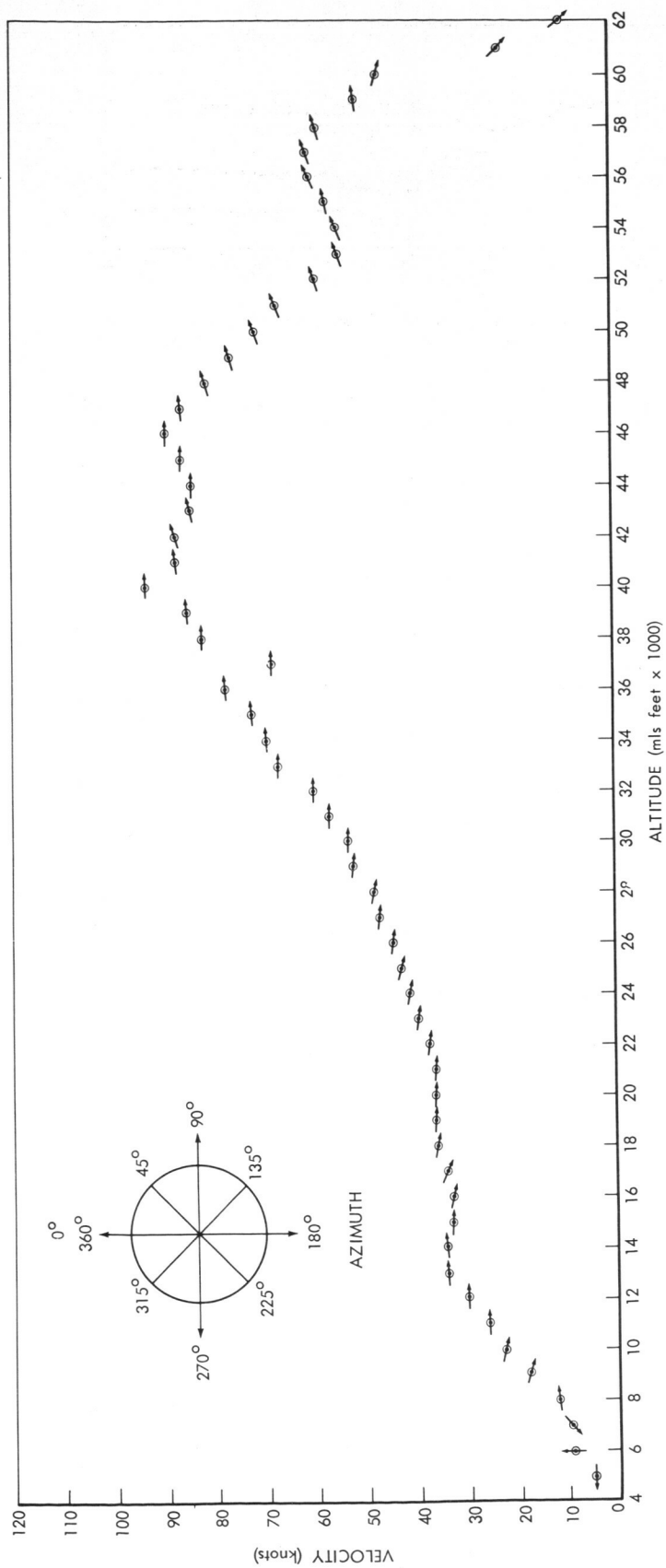


Figure 26. Flight 4.81 GG - Wind Velocity and Azimuth vs Altitude

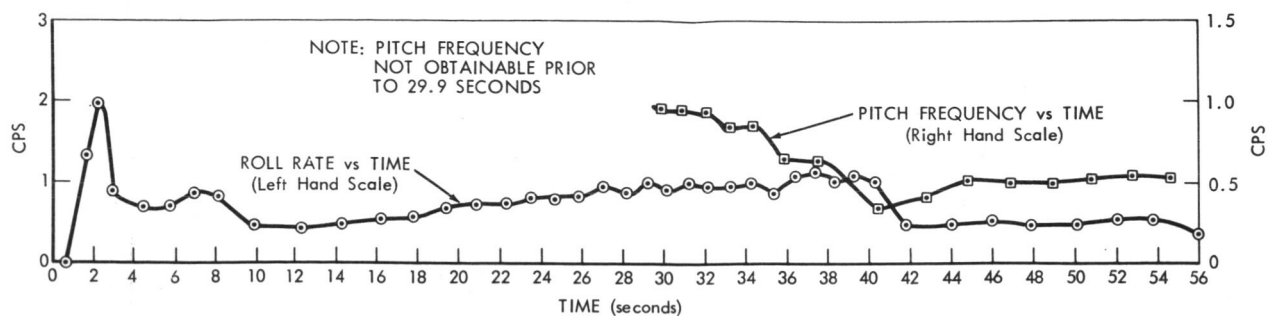


Figure 27. Flight 4.81 GG - Roll Rate, Pitch Frequency and Yaw Frequency vs Time

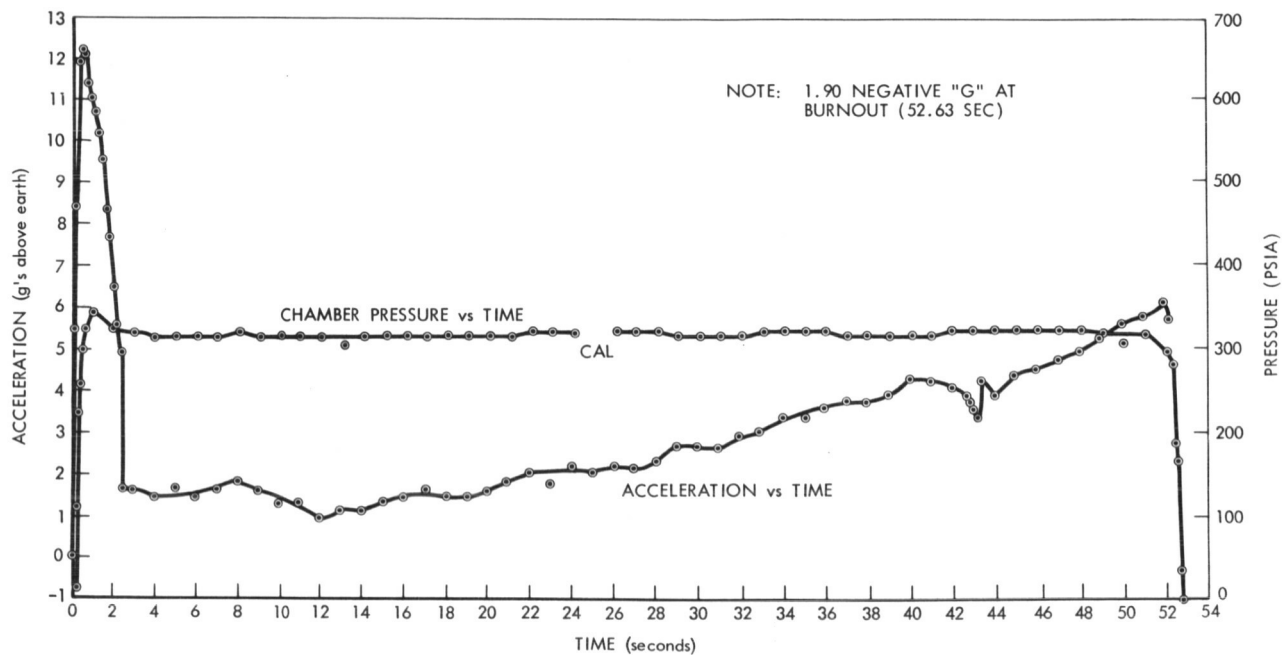


Figure 28. Flight 4.81 GG - Chamber Pressure and Acceleration vs Time

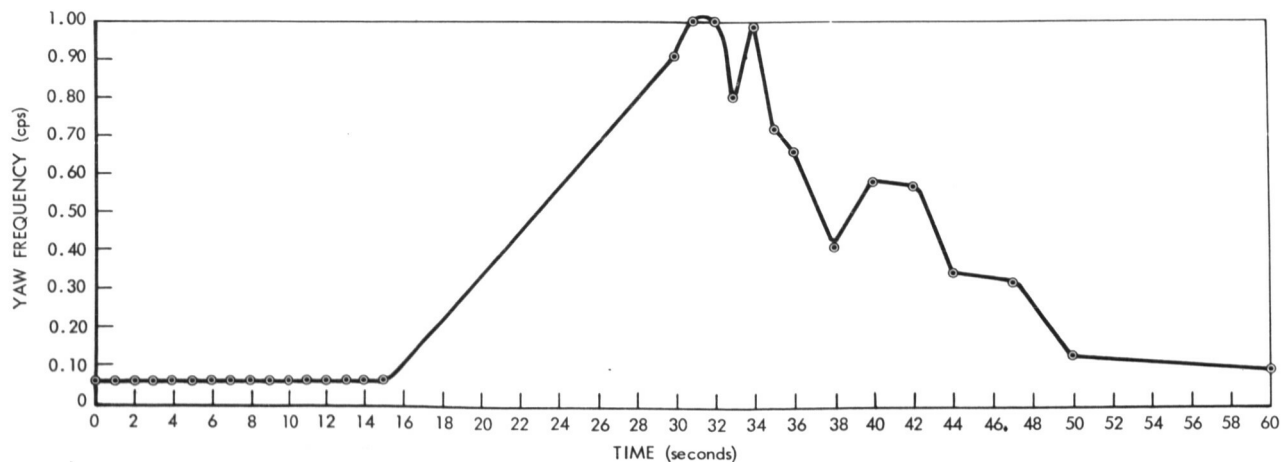


Figure 29. Flight 4.86 NA - Yaw Frequency vs Time

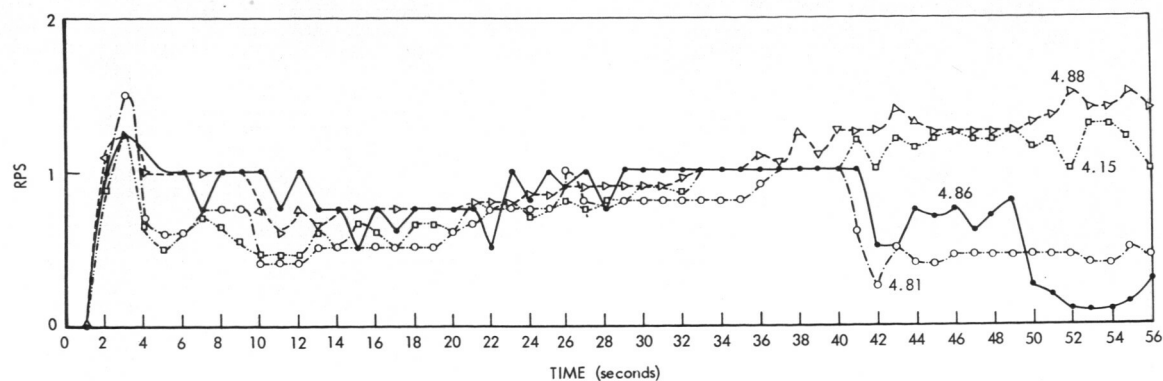


Figure 30. Flights 4.81 GG, 4.86 NA, 4.88 GG, 4.15 GG - Comparison; Roll Rate vs Time

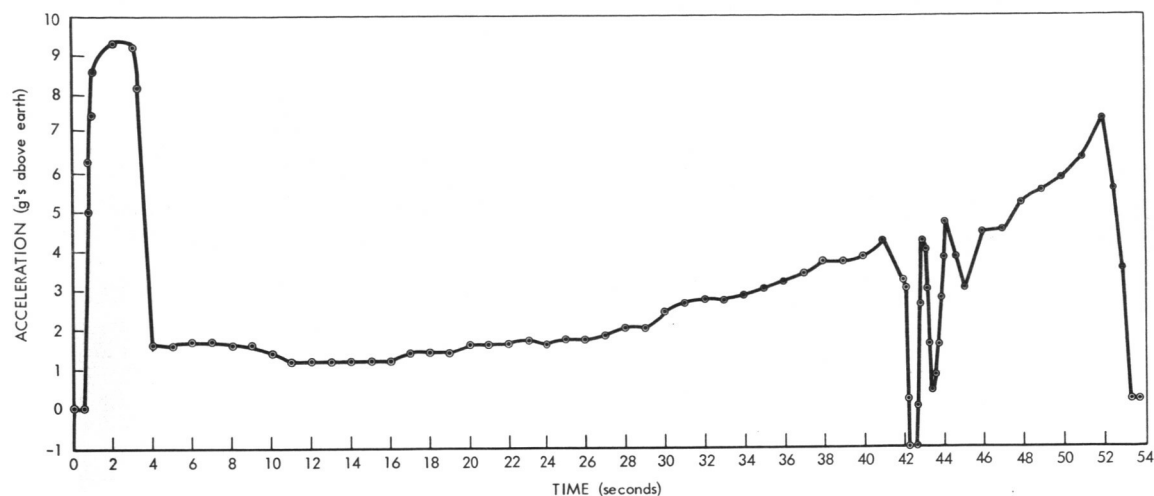


Figure 31. Flight 4.86 NA - Acceleration vs Time

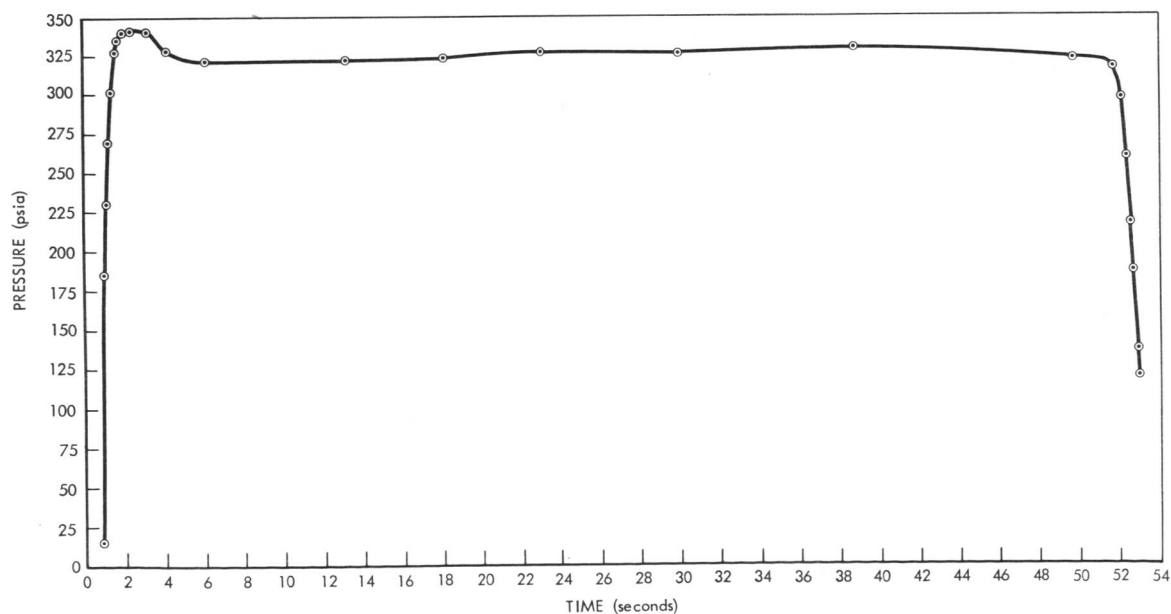


Figure 32. Flight 4.86 NA - Chamber Pressure vs Time

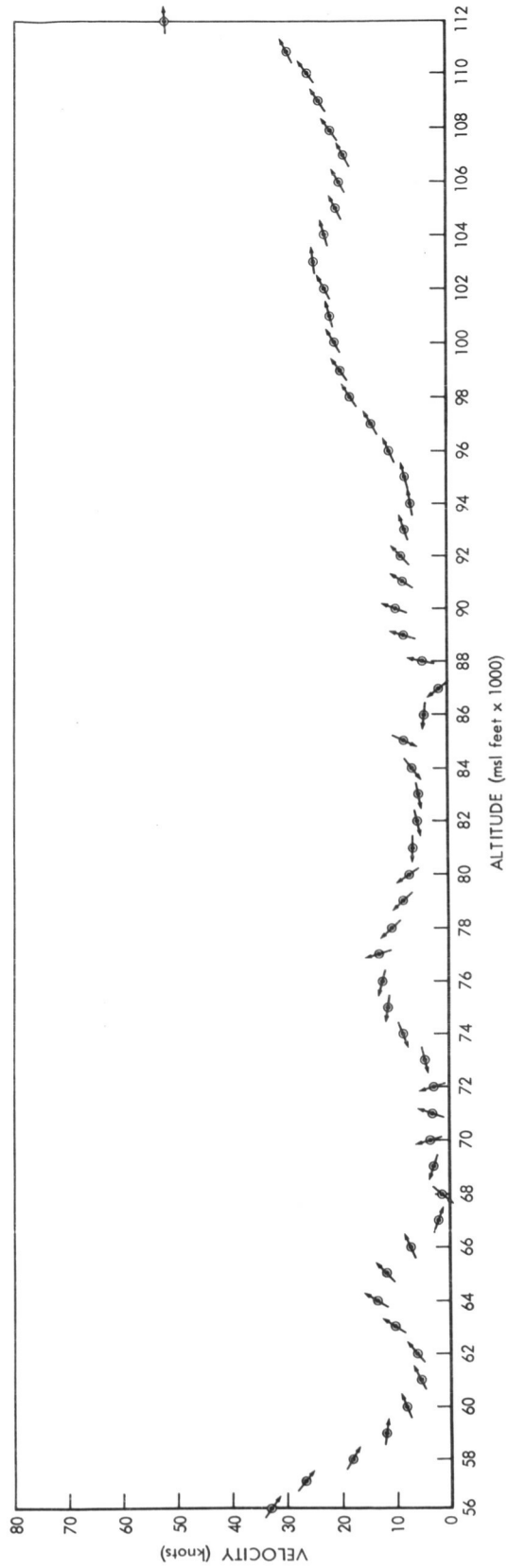
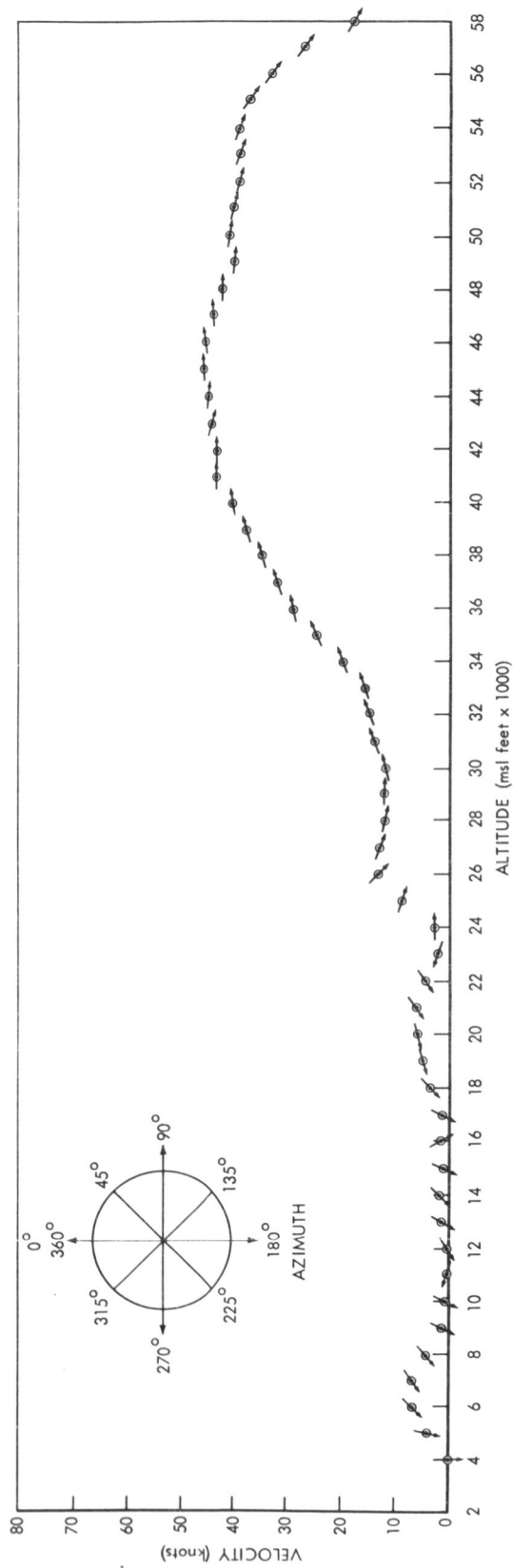


Figure 33. Flight 4.86 NA - Wind Velocity and Azimuth vs Time

Analysis and Conclusions, Flight Failure 4.81 GG and 4.86 NA—Immediately following these two failures, GSFC and the Space-General Corporation began intensive analyses into the effects on vehicle performance by several parameters: payload length; joint configuration; fin, thrust chamber, and structural misalignments; stability changes using cone cylinder nose cones. Data from these two flights were compared with similar flights and payload configurations, particularly 4.15 GG and 4.88 GT; aerodynamic and aerolastic studies were also undertaken by SGC and GSFC. The primary cause for failure was concluded to be pitch-roll lock-in which result from bi-modal instabilities arising in the pitch and roll frequencies. It is further concluded that the bi-modal instabilities resulted from a combination of a large number of payload joints, possible thrust chamber misalignments and payload unbalance. The following corrective measures, as a result of the various studies, were taken to allow the continued use of similar payload configurations:

- (1) An additional sixteen screws were added to the aft extensions.
- (2) Screws are individually torqued to 30 in-lb.
- (3) Bending tests and dynamic balancing are given greater consideration.
- (4) Thrust chamber misalignments and fin misalignments are measured.
- (5) Limiting stability criteria have been set up for various payload configurations.
- (6) Number of joints are reduced where possible.

Figure 34a provides payload dimensions and characteristics of Flight 4.81 GG. Figure 34b provides similar information for Flight 4.86 NA.

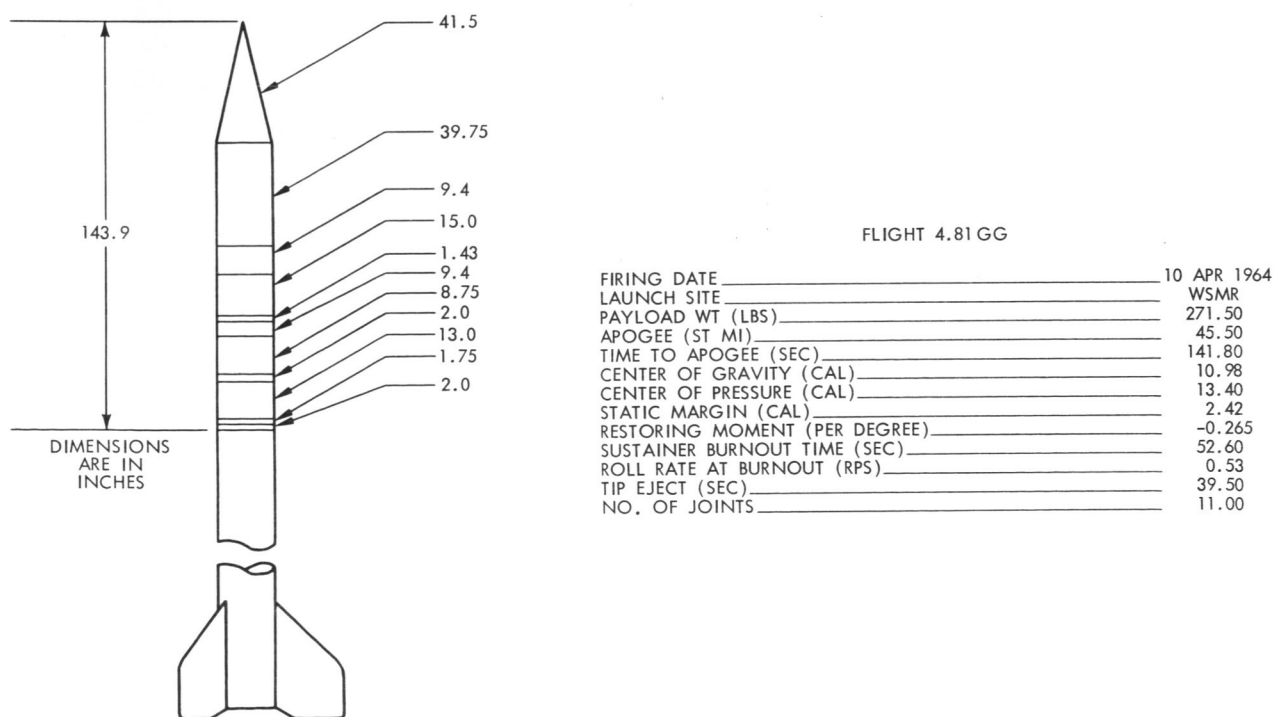
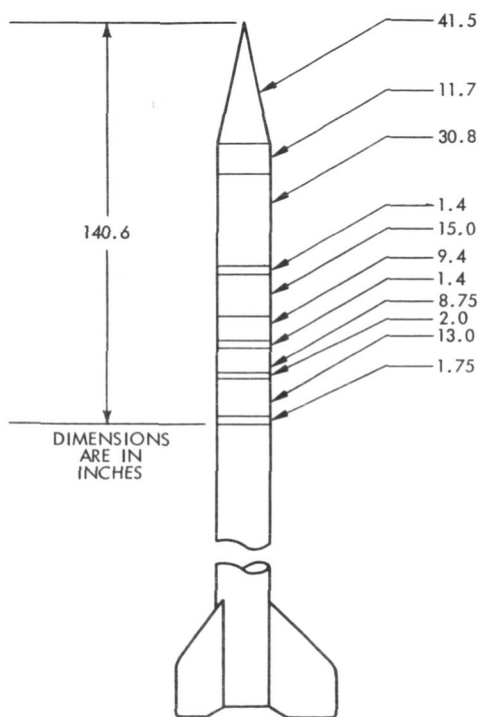


Figure 34a. Flight 4.81 GG - Dimensions and Flight Characteristics



FLIGHT 4.86 NA		
FIRING DATE		14 APR 1964
LAUNCH SITE		WSMR
PAYLOAD WT (LBS)		277.20
APOGEE (ST MI)		19.30
TIME TO APOGEE (SEC)		77.40
CENTER OF GRAVITY (CAL)		11.34
CENTER OF PRESSURE (CAL)		13.54
STATIC MARGIN (CAL)		2.20
RESTORING MOMENT (PER DEGREE)		-0.244
SUSTAINER BURNOUT TIME (SEC)		53.04
ROLL RATE AT BURNOUT (RPS)		not observed
TIP EJECT (SEC)		61.50
NO. OF JOINTS		11.00
SUSTAINER FAILED		

Figure 34b. Flight 4.86 NA - Dimensions and Flight Characteristics

Flight 4.113 GA-GI

NASA vehicle 4.113 GA-GI was launched from the WSMR on 21 April. A failure in the propulsion system prevented the rocket from going higher than 7 statute miles. The primary objectives were to recover physical evidence of hypervelocity micrometeorite impacts, to collect samples of low velocity cosmic dust, and to measure electron densities below 120 km; none of these, of course, were realized.

Unusual sounds at lift-off, variously described as a low pitched scream, whine, and whistle, were observed. The atmosphere around the launch tower contained a significant IRFNA odor, and all indications are that the rocket lifted off with an oxidizer-rich mixture ratio in the thrust chamber, accompanied by a low frequency instability. At approximately T+27.5 seconds, observers reported viewing a bright flash when the tail can exploded. Telemetry was lost immediately and the rocket began to tumble, going into a flat spin, slowly falling to an impact approximately 5 miles northeast of the tower. The remains of the rocket were recovered and returned for investigation. Although this failure was unrelated to the previous two, it was the third consecutive one in twelve days. All launch activity was halted while an analysis could be undertaken. All performance data was immediately reduced; excellent flight photo coverage was also available.

In addition to the tracking cameras, two colored documentary cameras followed the rocket from launch to impact. These films were also analyzed in detail by GSFC. The results of this investigation are summarized in reference 3. During post flight inspection of the recovered motor, it was observed that the fuel coolant tap and the thrust chamber pressure tap were missing (Figure 35) and the thrust structure was bent. The aft bulkhead (fuel tank) and motor structure were cut from the tankage. Analysis of these parts showed that there were great amounts of burned aniline residue deposits on the outside of the bulkhead; there were no indications, however, of intensive heat since the control and instrumentation wiring were clean and intact (See Figure 36). No damage was observed on the burst diaphragm ring. Inspection of the thrust chamber revealed a trapped "O" ring in the fuel strainer (See Figure 37); this mysteriously came off the fuel shut off valve. This "O" ring did not in any way contribute to the failure.



Figure 35. Flight 4.113GA-GI - Thrust Chamber Motor Jacket Showing Broken PC and Fuel Taps

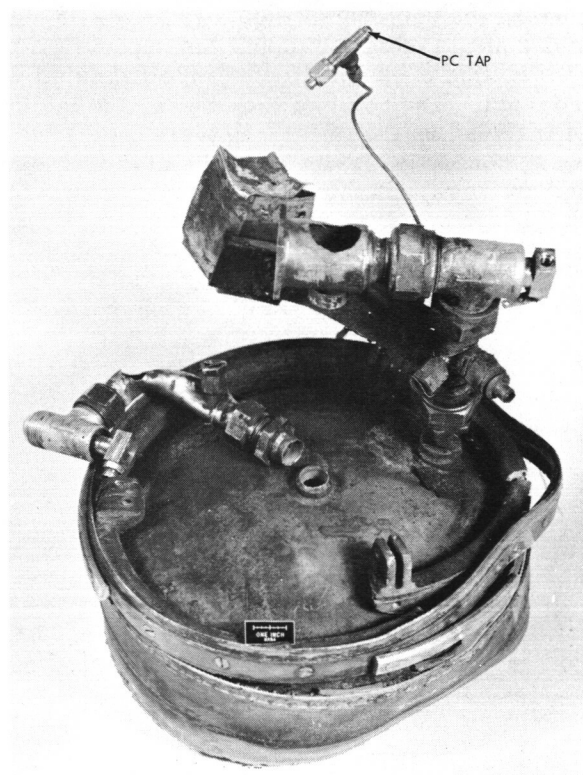


Figure 36. Flight 4.113GA-GI - Aft Fuel Tank Bulkhead Showing Burned Aniline Deposits

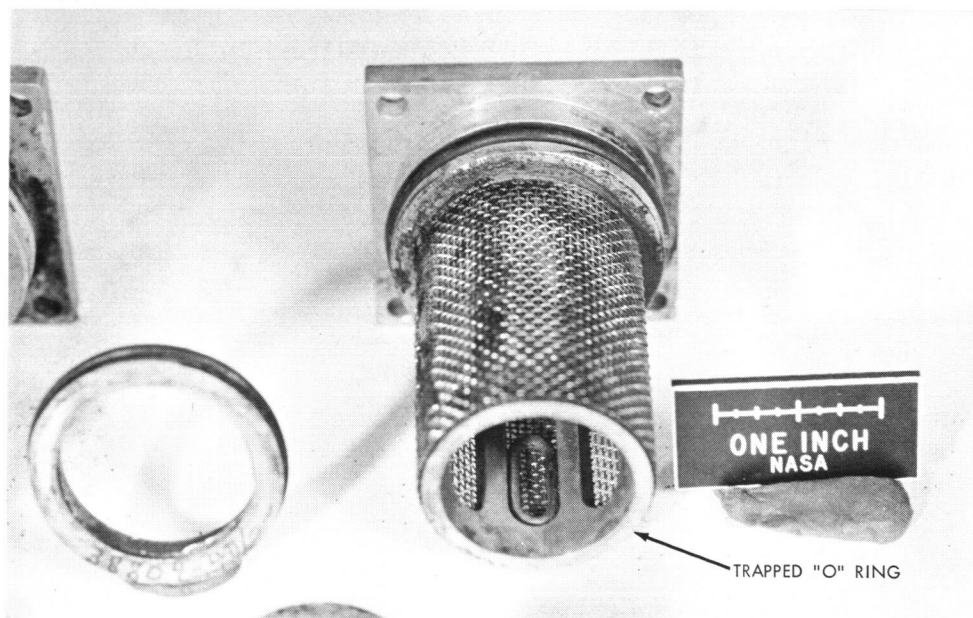


Figure 37. Flight 4.113GA-GI - Fuel Strainer Showing Trapped "O" Ring

Comparing the performance data (Figures 38 and 39) with other flights, examination of recovered components, discussions of the reports given by observers at the launch, and frame-by-frame investigation of the photo coverage indicated very strongly that the primary cause for failure was a hard start. The color of the smoke, the ignition flame out, and re-ignition that occurred as the rocket traveled up the tower, all were indicative of a rocket motor that has encountered a hard start. These conditions followed by the acid rich smoke, almost completely obscuring the booster, are indicative of unstable combustion, the result of a hard start.

Several factors are deduced as possible causes for the hard start; improper propellant tank ullage, an improper breakage of fuel or oxidizer burst diaphragms and/or an improper bleeding of the thrust chamber jacket. Other flight anomalies that were observed resulted from the extreme

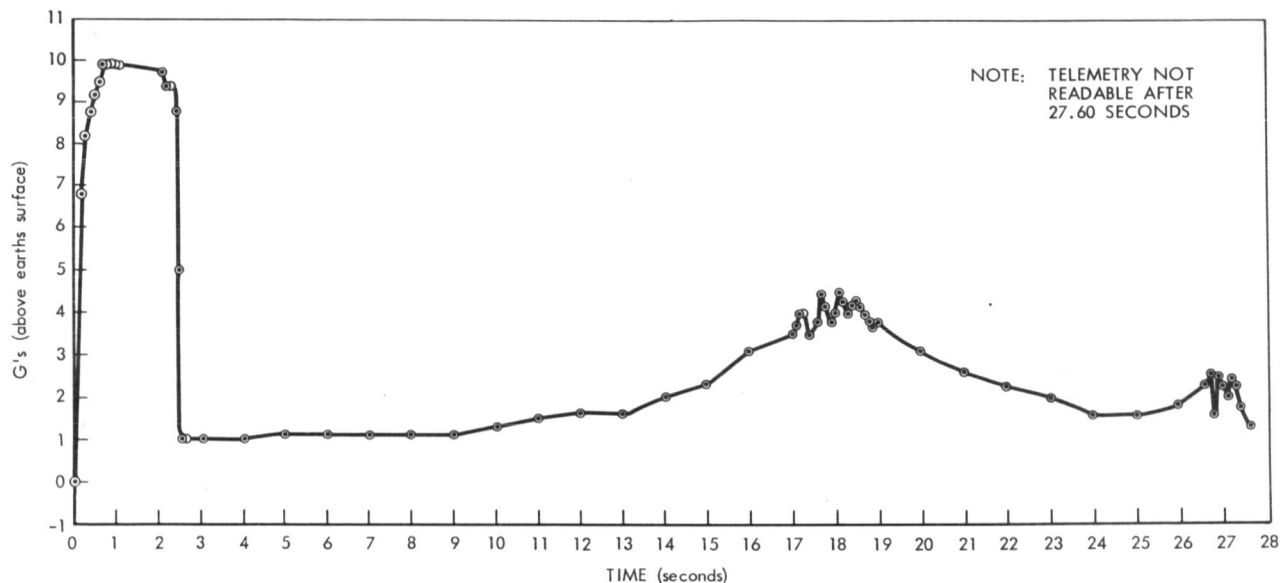


Figure 38. Flight 4.113GA-GI - Acceleration vs Time

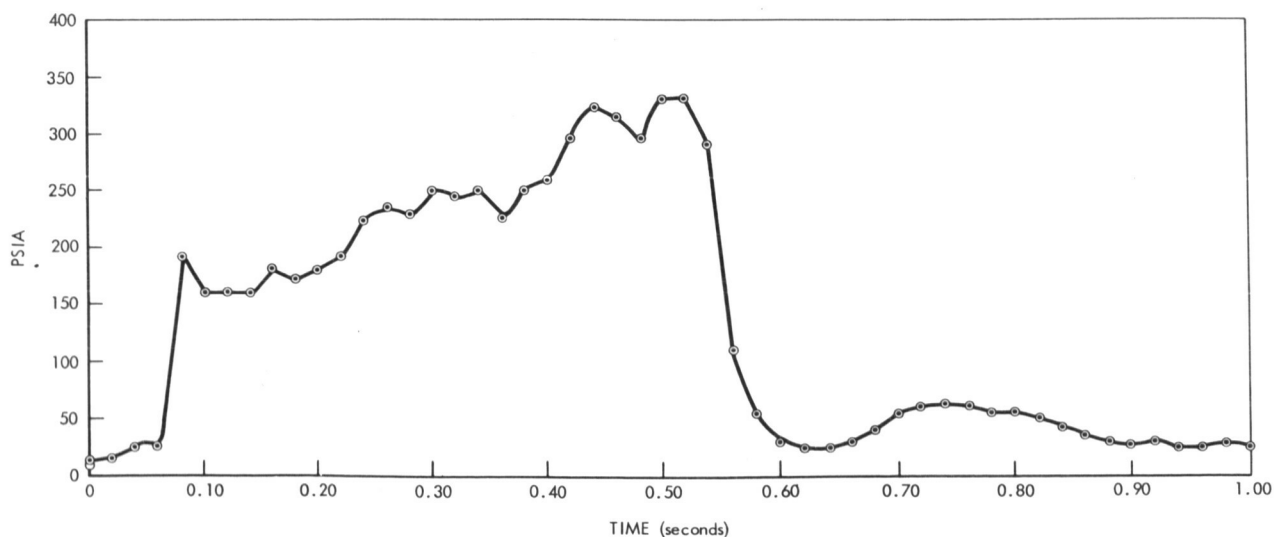


Figure 39a. Flight 4.113GA-GI - Chamber Pressure vs Time (0-1 sec)

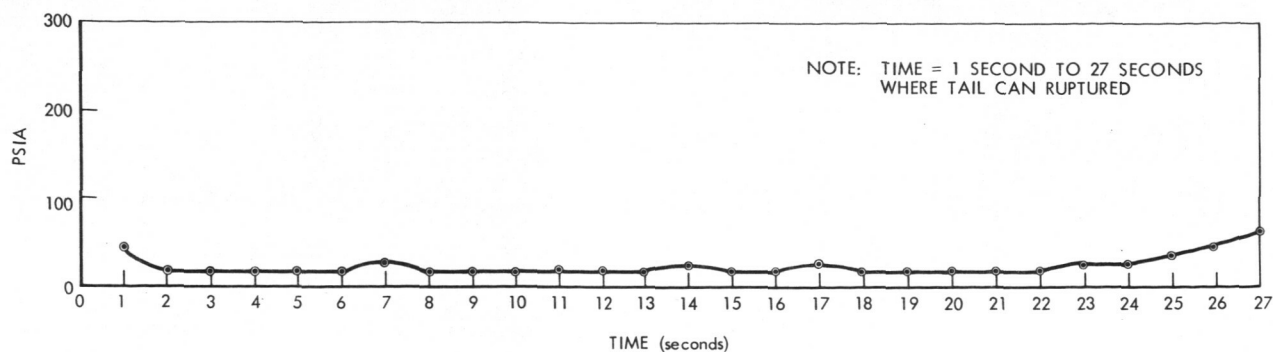


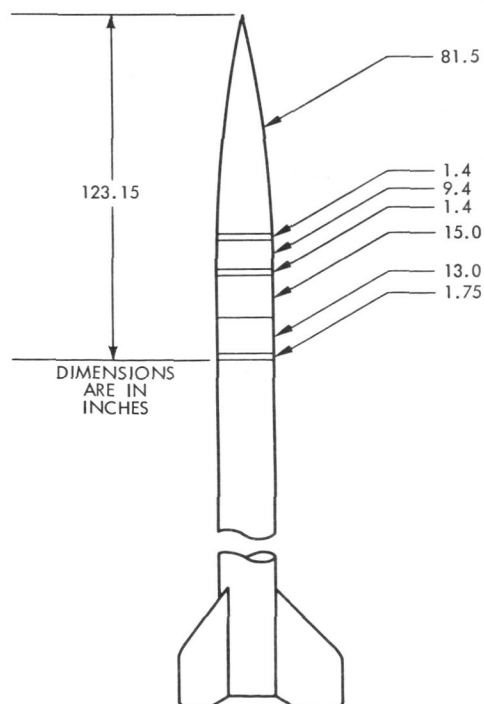
Figure 39b. Flight 4.113GA-GI - Chamber Pressure vs Time (0-27 sec)

back pressures generated from the hard start; the pressures were sufficient to break the fuel and thrust chamber pressure taps (See Figure 41). With fuel flowing out of the fuel line tap, the motor was operating under an oxidizer rich condition until approximately T+27 seconds when the tail can exploded.

The propulsion system failure experienced on this flight served to illustrate the continued and increased vigilance that must be given during rocket preparation. As a result of these investigations several actions were instituted:

Pre-flight vehicle hardware checks were increased; propellant temperatures are more carefully regulated; more efficient method of bleeding air from the thrust chamber jacket is being proposed; quality control for assuming specified burst pressures of diaphragms was increased.

Figure 40 gives payload dimensions and characteristics of this rocket and its flight.



FLIGHT 4.113GA-GI

FIRING DATE	21 APR 1964
LAUNCH SITE	WSMR
PAYLOAD WT (LBS)	239.00
APOGEE (ST MI)	6.60
TIME TO APOGEE (SEC)	29.20
CENTER OF GRAVITY (CAL)	10.43
CENTER OF PRESSURE (CAL)	13.60
STATIC MARGIN (CAL)	3.23
RESTORING MOMENT (PER DEGREE)	-0.103
SUSTAINER BURNOUT TIME (SEC)	27.50
ROLL RATE AT BURNOUT (RPS)	not observed
TIP EJECT (SEC)	not accomplished
NO. OF JOINTS	7.00
SUSTAINER FAILED	

Figure 40. Flight 4.113GA-GI - Dimensions and Flight Characteristics

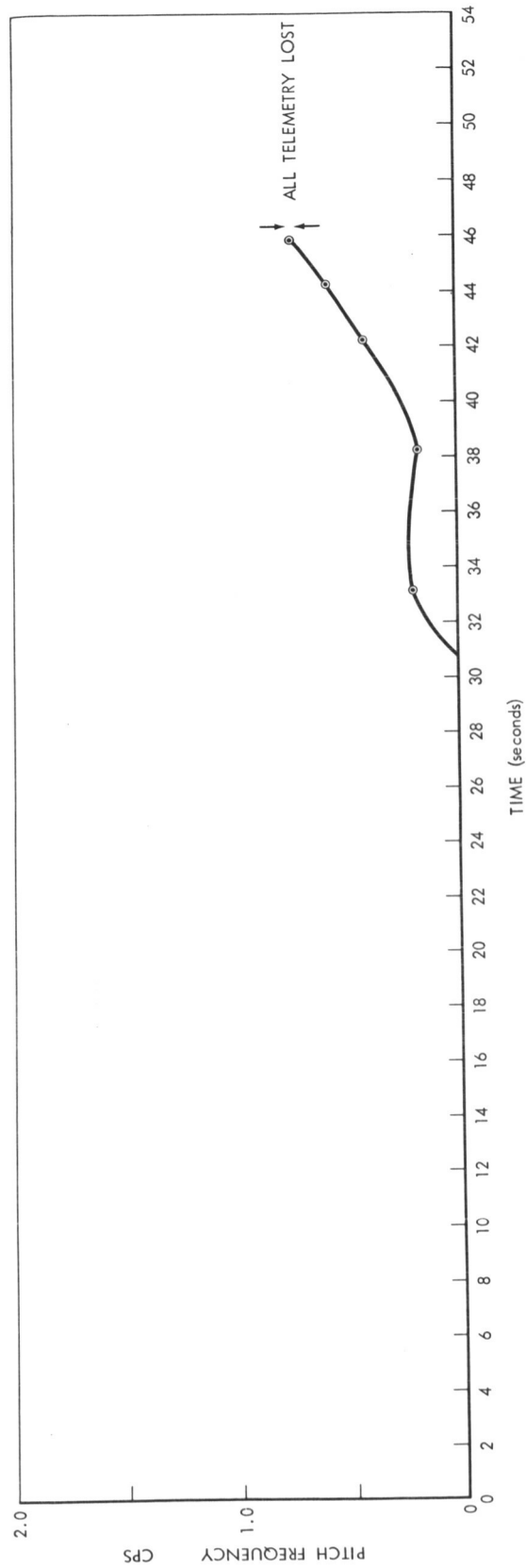
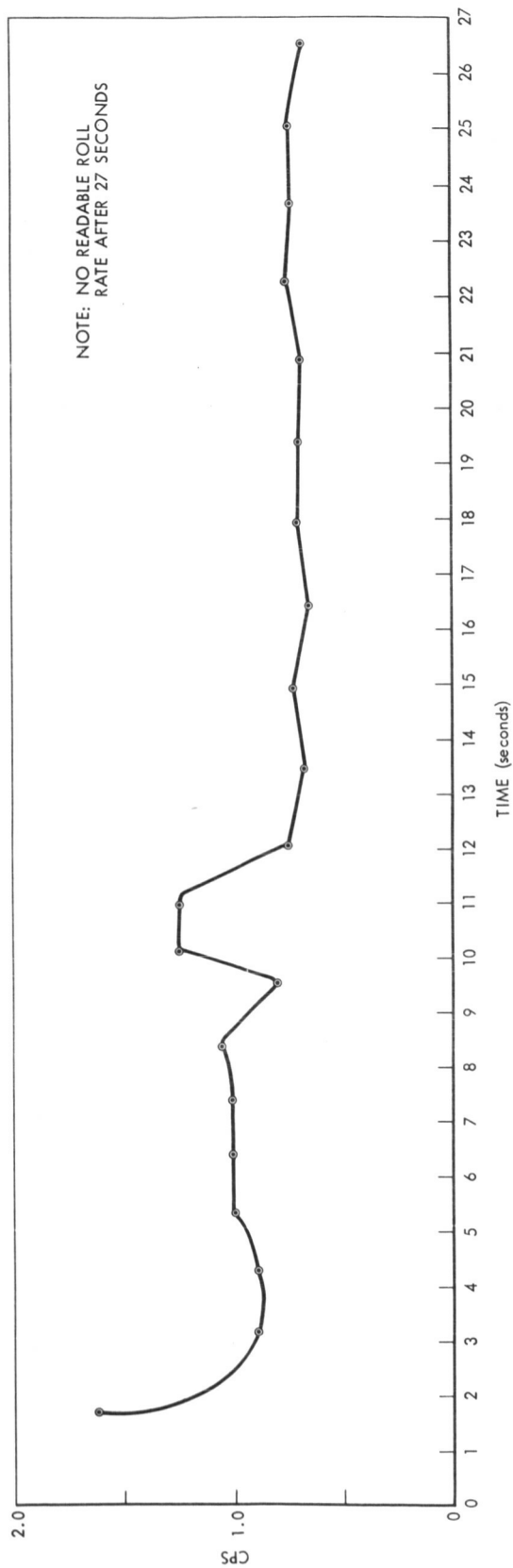


Figure 41. Flight 4.113 GA-GI - Roll Rate and Pitch Frequency vs Time

NASA Flight 4.67 NP

NASA flight 4.67 NP was successfully launched from WSMR on 10 June. This was the first Aerobee flight following investigations of the three consecutive failures discussed in the three previous discussions. Primary objectives of the experiment were to record micrometeorite impacts on an inflatable paraglider with capacitor-type sensing instruments. Additional objectives included the collection of micrometeorites and testing of the paraglider's re-entry capabilities. The payload consisted of an unpressurized standard ogive nose cone, a 39" extension which housed the camera, folded paraglider, the packing cannister and the attachment rings, and a 15" instrumentation extension with four quadraloop antennas mounted on the external skin. The sustainer was altered by the addition of 3 retro nozzles in the tail. These were to further assure separation of the spent sustainer from the payload during flight by using residual helium from the propulsion system. Flow to the nozzles was controlled by two conax squib valves. An independent power supply and arming device were added to effect the separation of the payload and the spent sustainer.

The vehicle performed as predicted, attaining a peak altitude of 96.4 statute miles. All instrumentation performed well. A switching circuit failed to actuate the nose cone and telemetry severance system prior to re-entry. Also a "g"-reduction timer which was programmed for three events failed to actuate. These events were to shut-off the oxidizer and fuel valves, to channel switch from one function to another, and to arm the initiators for severing the nose cone prior to re-entry. A back-up ground command successfully shut off the fuel and oxidizer valves, thus conserving the remaining helium for the despin system and the retro-rockets.

Figures 42 through 44 represent reduced flight performance data for this flight. These are included to provide examples of a typical heavy Aerobee 150 rocket's performance.

An onboard slow speed movie camera photographed the paraglider from lift-off, up through apogee, and during re-entry. The film showed that the retro firing performed as expected. The paraglider was ejected, inflated, and began to glide as expected; the heavy nose tip which did not eject caused the paraglider to re-enter at a much more rapid rate than predicted. Although the paraglider membranes ruptured due to excessive loading, the paraglider glided to impact where it was recovered. The paraglider itself as shown in Figure 45 was approximately 14 feet in length, exposing approximately 200 square feet of sensors.

Figure 46 gives payload dimensions and characteristics of this rocket and its flight.

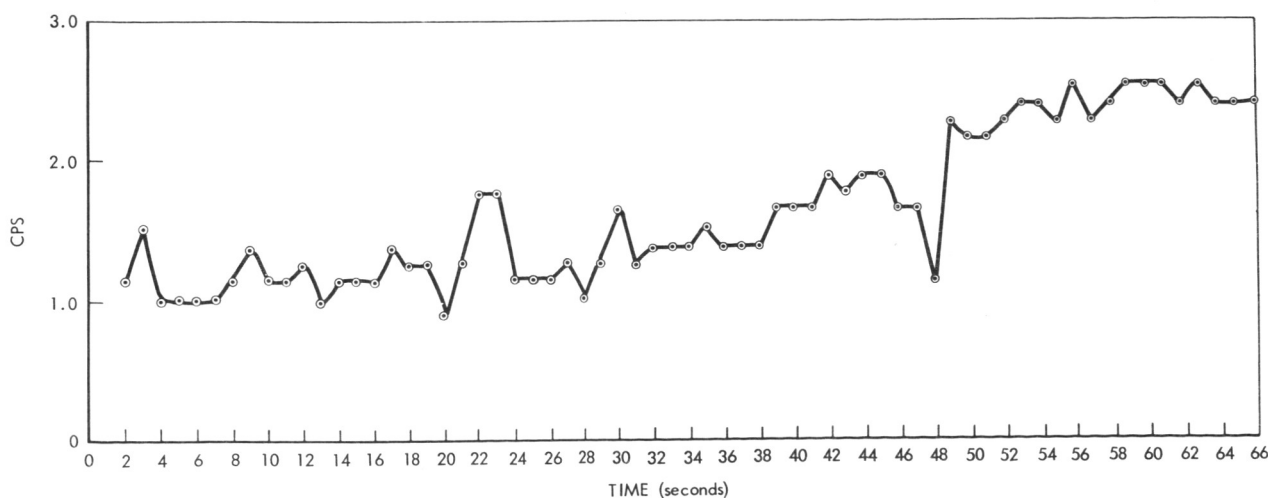


Figure 42. Flight 4.67 NP - Roll Rate vs Time

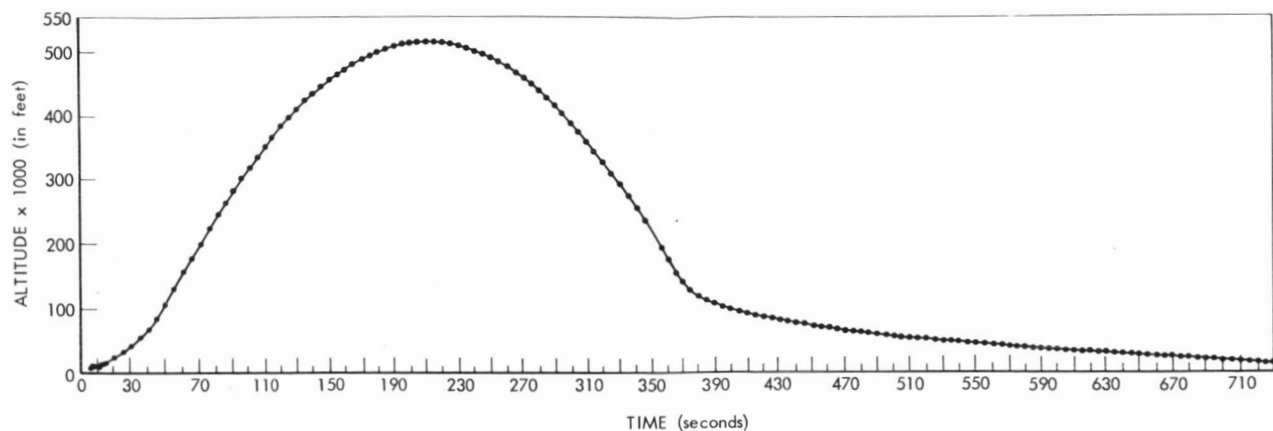


Figure 43. Flight 4.67 NP - Altitude vs Time

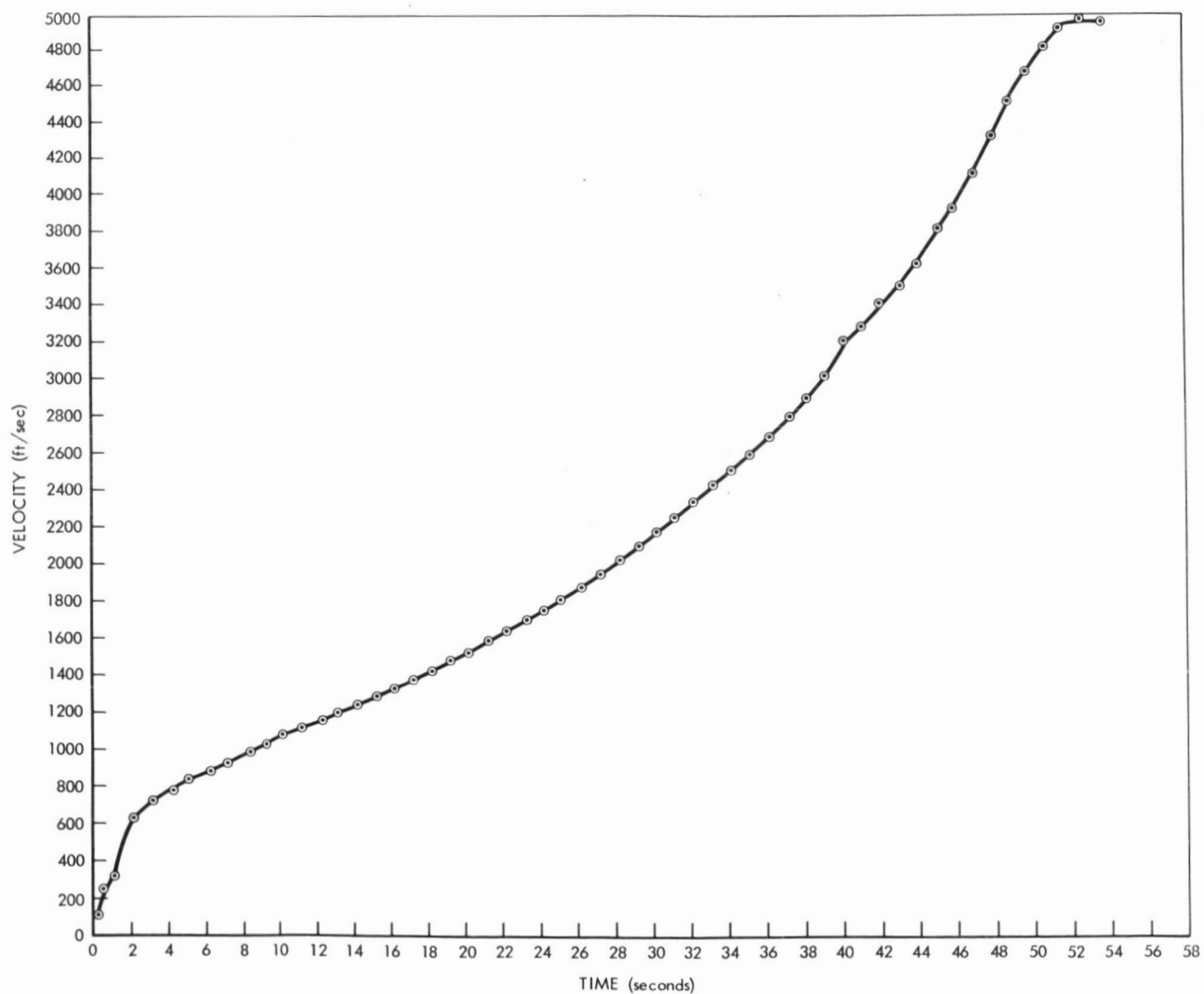


Figure 44. Flight 4.67 NP - Velocity vs Time

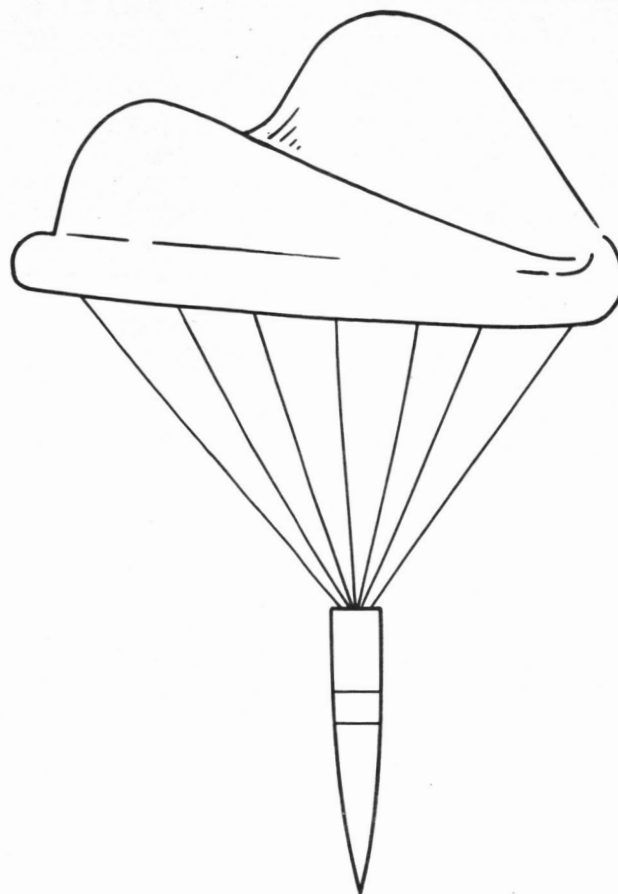
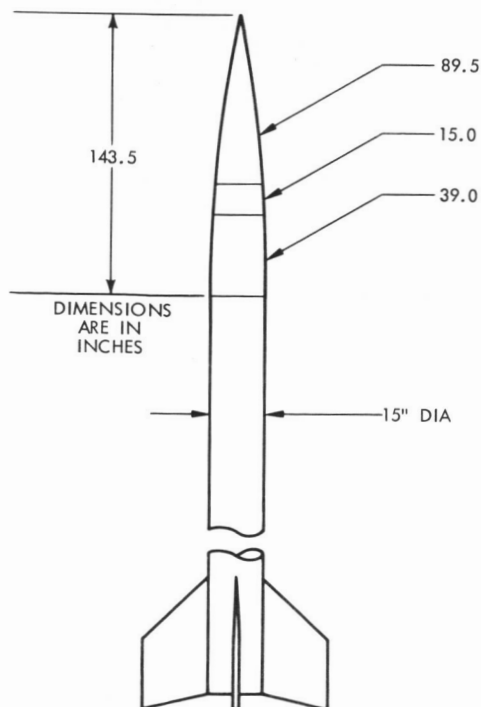


Figure 45. Configuration of Inflatable Micrometeoroid Paraglider used on Flight 4.67 NP



FLIGHT 4.67 NP

FIRING DATE	10 JUNE 1964
LAUNCH SITE	WSMR
PAYLOAD WT (LBS)	353.90
APOGEE (ST MI)	96.40
TIME TO APOGEE (SEC)	211.10
CENTER OF GRAVITY (CAL)	11.40
CENTER OF PRESSURE (CAL)	15.00
STATIC MARGIN (CAL)	3.60
RESTORING MOMENT (PER DEGREE)	0.396
SUSTAINER BURNOUT TIME (SEC)	52.10
ROLL RATE AT BURNOUT (RPS)	2.50
NO. OF JOINTS	3.00

Figure 46. Flight 4.67 NP - Dimensions and Flight Characteristics

NASA Flights 4.107 GE and 4.108 GE

Both NASA flights 4.107 GE and 4.108 GE were successful rocket flights, launched consecutively from the Ft. Churchill launch facility in Manitoba, Canada. Scientific objectives were to study the very low energy heavy nuclei cosmic rays as a part of the International Quiet Sun Year Studies (IQSY). Specific objectives were:

- (1) Measurement of fluxes and energy spectra of heavy nuclei in the very low energy region (which cannot be studied by balloon)
- (2) Examination of the composition and relative abundance of heavy nuclei in this low energy region
- (3) Study of the ratio of light nuclei ($3 \leq Z \leq 5$) to medium ($6 \leq Z \leq 9$) to heavy ($Z \geq 10$)
- (4) Measurement of alpha particles at these energies

Additional objectives included the launching of each vehicle at the same time a University of Minnesota high altitude cosmic ray balloon was in the air. This data, when compared with the balloon data and the data from a similar Aerobee flight in 1963 (Flight 4.91 GS), provided useful data for studying the effects of solar modulation of cosmic rays. These flights are especially significant in this regard since they occurred very close to the minimum of solar activity during the present solar cycle.

Measurements were made by placing large sheets of nuclear emulsions in a recoverable payload. The emulsions were to be exposed after burnout and later to be retracted before impact for their protection.

In each case the flights were successfully accomplished. For flight 4.107 the rocket performance was greater than predicted while the experimental results were slightly less than expected due to a malfunction within the experiment. NASA flight 4.108 performed slightly under predicted; however the experimental results were completely successful. In both cases the excellent ground support received and the cooperation provided in the recovery operation contributed greatly to the successfulness of the mission.

NASA Flight 4.107 GE—NASA flight 4.107 GE was launched on 23 July from Ft. Churchill, Canada (See Figure 47). The rocket experienced a normal lift off and launch operation. The booster and sustainer functioned properly; sustainer burning was 2 seconds longer than predicted. The peak altitude was 4.5 statute miles above the theoretical predictions. All instrumentation performed satisfactorily during flight and excellent data was obtained. Figures 48 and 49 show the reduced acceleration and chamber pressure data experienced on this flight.

The recovery package, including a Sarah Beacon, functioned as planned and the parachute was easily spotted from the air. A winged aircraft directed the recovery of the payload by an Air Force helicopter. The nose cone was recovered in excellent condition. Unfortunately a timer failure caused two of the three trays, which contained emulsions, not to retract completely. Some of the emulsions were damaged by the re-entry heat and moisture upon landing.

Figure 50a provides an excellent view of the experiment section shown looking down from the top. In this figure the mechanisms and motors which were used to extract and retract the emulsion plates during flight are clearly identifiable. Figure 50b shows the vehicle configuration during weight and center of gravity determination.

Figure 51 gives payload dimensions and characteristics of this rocket and its flight.

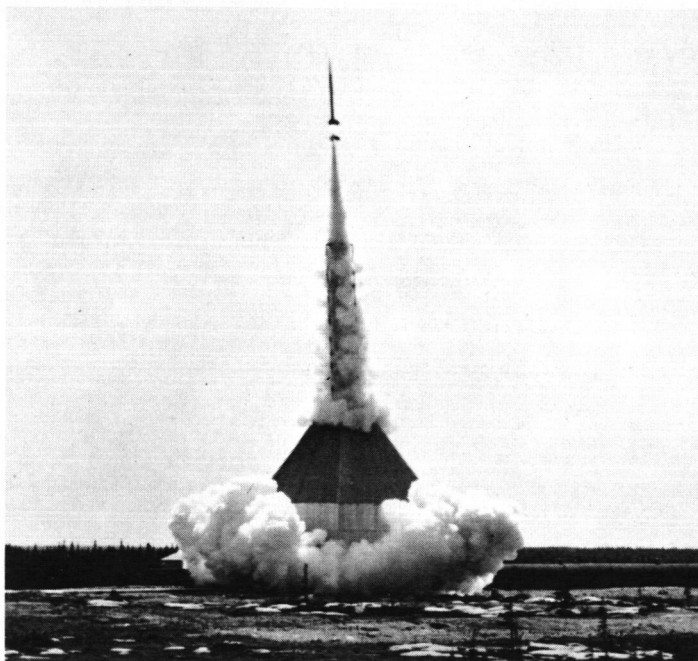


Figure 47. Aerobee Rocket 4.107 GE Launch from Fort Churchill Range

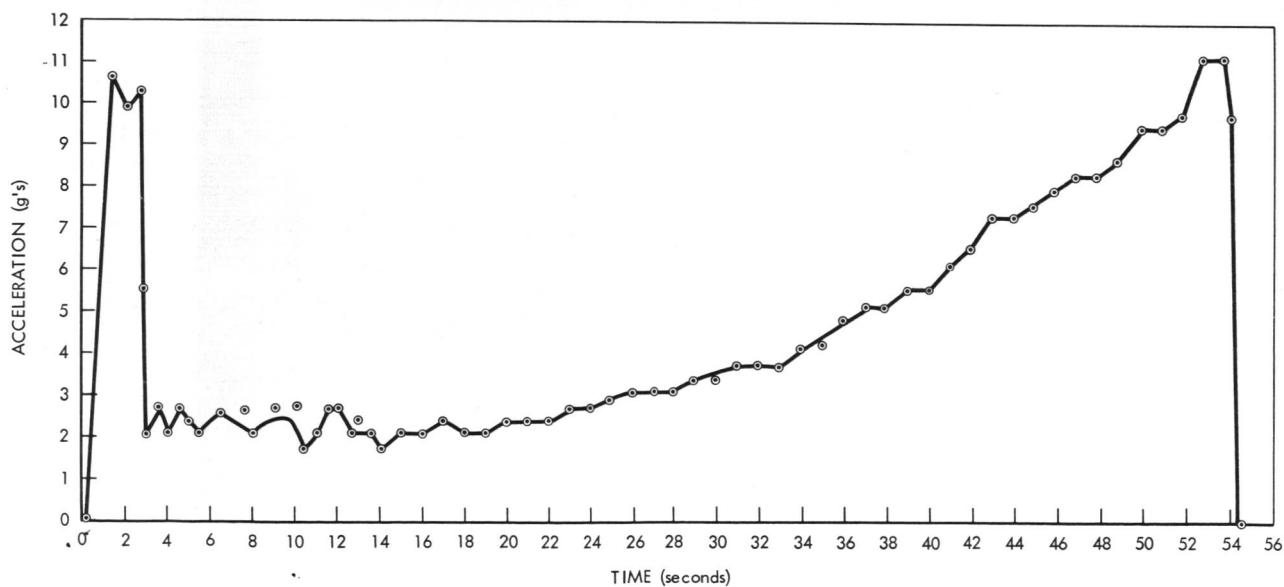


Figure 48. Flight 4.107 GE - Acceleration vs Time

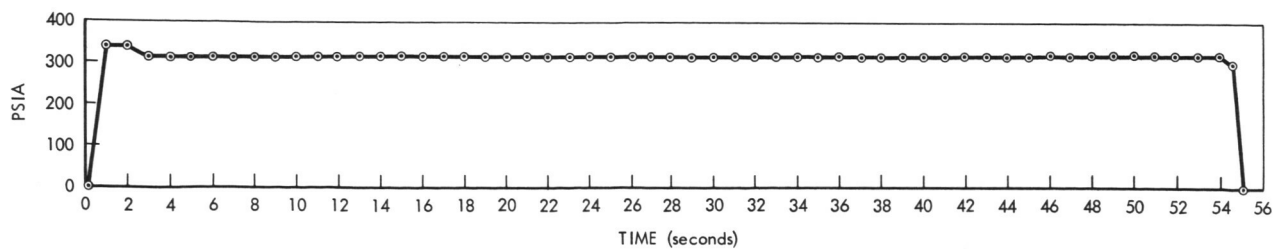


Figure 49. Flight 4.107 GE - Chamber Pressure vs Time

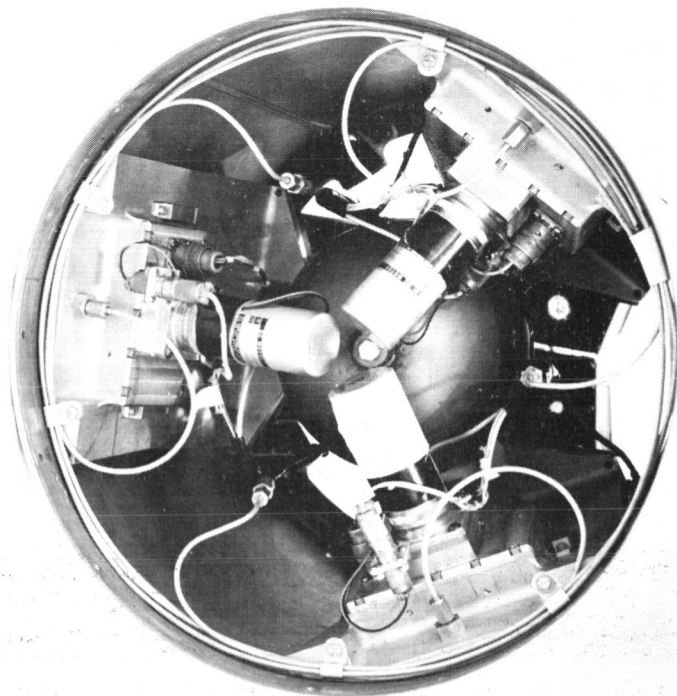


Figure 50a. Flight 4.107 GE - Experiment Section

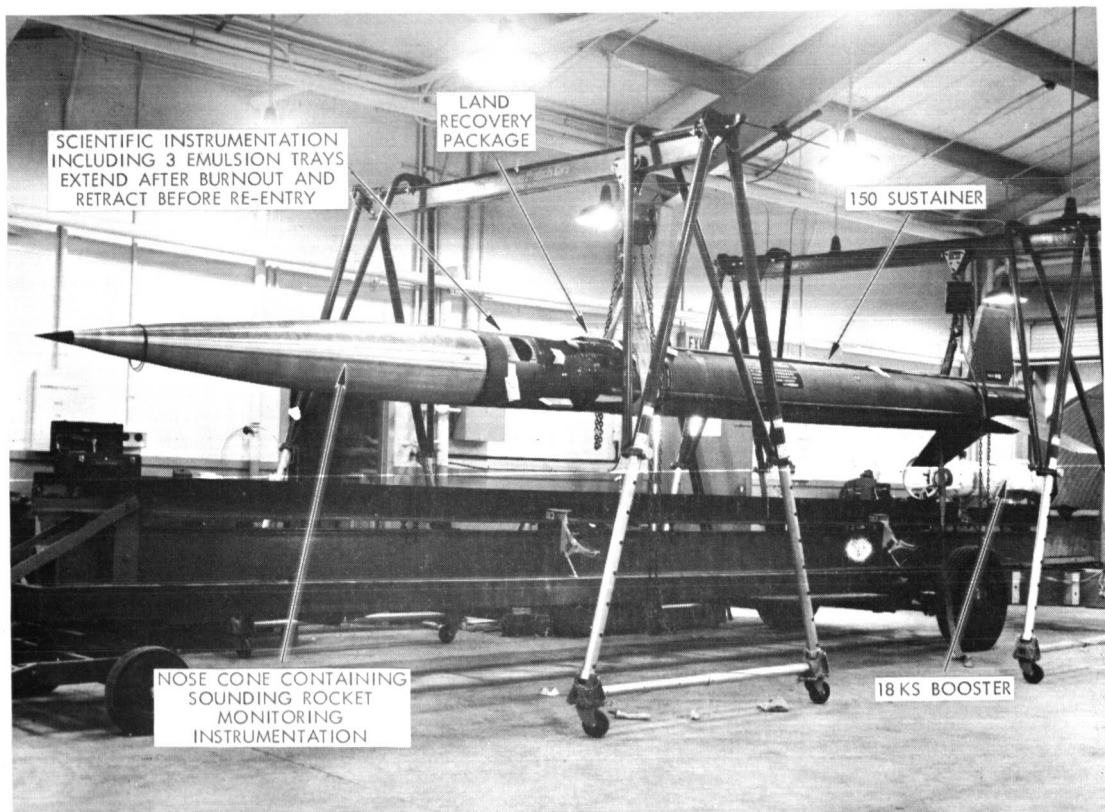


Figure 50b. Aerobee 4.107 GE - Balancing of Rocket and Payload

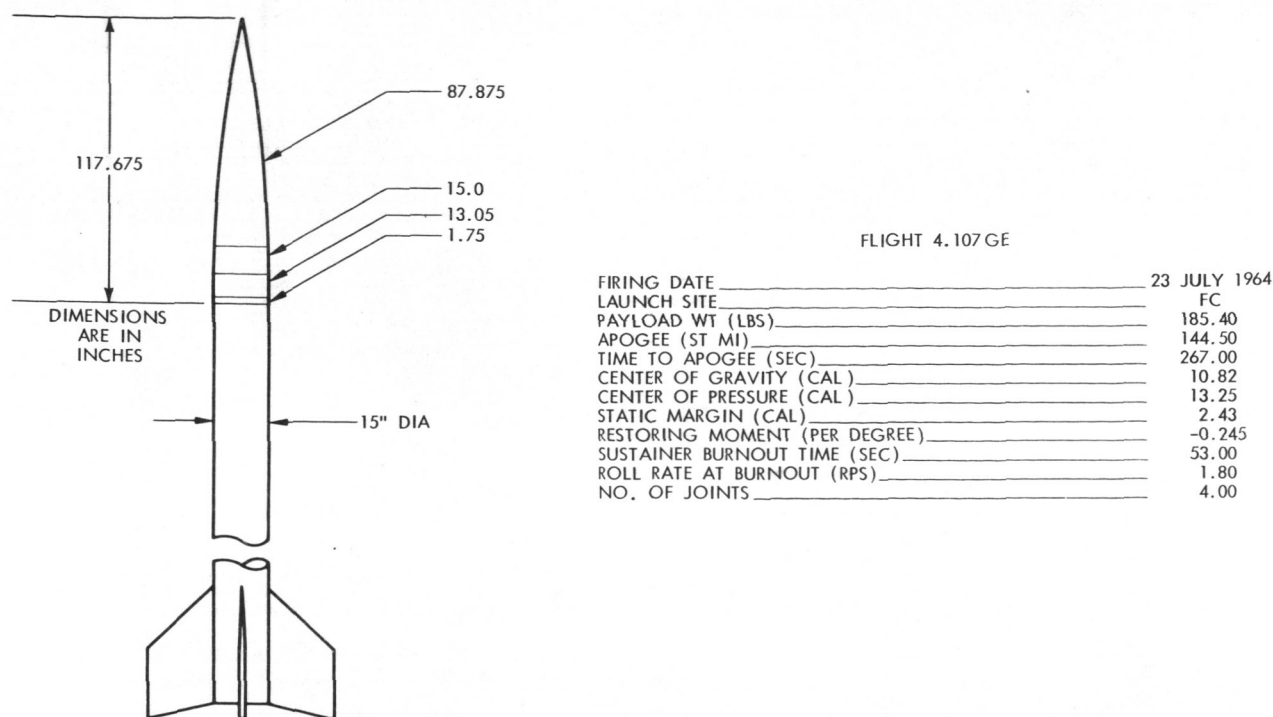


Figure 51. Flight 4.107 GE - Dimensions and Flight Characteristics

NASA Flight 4.108 GE—NASA rocket 4.108 GE was launched two days after NASA flight 4.107 GE on 25 July. This rocket was identical in payload and mission, and it had been planned for use as a back-up rocket in case the scientific objectives of 4.107 GE were not completely met. The rocket and all instrumentation performed well, although the peak altitude attained was slightly lower than predicted. The payload functioned perfectly and excellent data were reportedly received.

At 63 seconds the three emulsion plates were extended and then retracted completely at 435 seconds, prior to re-entry. The recovery system functioned properly, and with assistance from the SARAH beacon which was included in the recovery package, a winged aircraft used to spot the payload for recovery had no difficulty in locating the payload. The actual recovery was effected soon thereafter by helicopter. Figure 52 shows this operation. Figure 53 shows a picture of the experiment section (minus the extension casing) being tested at Churchill by GSFC engineers.

(1) At recovery it was noted that the SARAH beacon antenna was shorting on the parachute container support brackets thus giving an intermittent transmission accompanied by a frequency shift. This was concluded to result from improper positioning of the beacon in the recovery package.

(2) From magnetometer data received, there were indications that payload coning throughout the flight was very slight. This was excellent for purposes of the experiment.

This vehicle was the 100th rocket launched at Churchill Research Range under U.S. Air Force management, Colonel Jerry F. Flicek, USAF, Commanding. Figure 54 shows the presentation ceremony commemorating the event, where the recovered parachute and nose cone were presented to the range by NASA-GSFC personnel as mementoes.

Figure 55, 4.108 GE, gives payload dimensions and characteristics of this rocket and its flight.



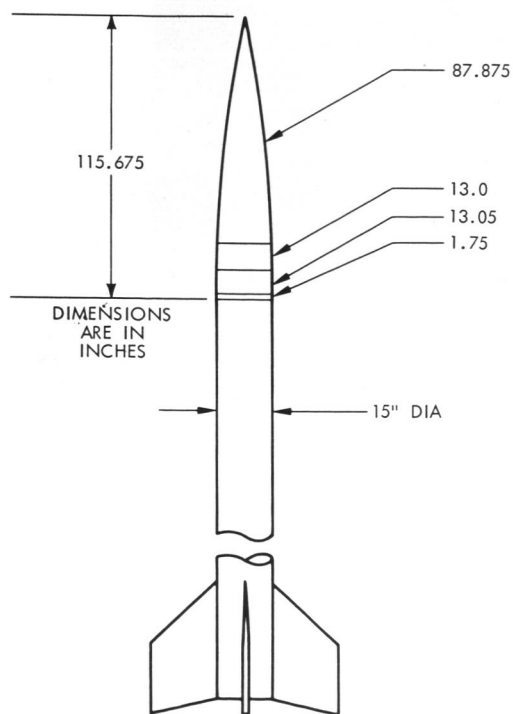
Figure 52. Recovery of Aerobee 4.108 GE Payload



Figure 53. Flight 4.108 GE - Experiment Section without the Extension Casing



Figure 54. Presentation Ceremony Commemorating 100th Rocket
Launched at Fort Churchill under Air Force Management



FLIGHT 4.108 GE

FIRING DATE	25 JULY 1964
LAUNCH SITE	FC
PAYLOAD WT (LBS)	179.50
APOGEE (ST MI)	133.70
TIME TO APOGEE (SEC)	251.00
CENTER OF GRAVITY (CAL)	10.70
CENTER OF PRESSURE (CAL)	13.25
STATIC MARGIN (CAL)	2.55
RESTORING MOMENT (PER DEGREE)	-0.255
SUSTAINER BURNOUT TIME (SEC)	51.70
ROLL RATE AT BURNOUT (RPS)	2.20
NO. OF JOINTS	4.00

Figure 55. Flight 4.108 GE - Dimensions and Flight Characteristics

NASA Flight 6.10 GA

NASA flight 6.10 GA was launched successfully from the Fort Churchill Range on 28 July. The objective of the flight was to simultaneously measure the electron and neutral particle temperatures in the high altitude region between 120-360 kilometers. A secondary intended objective was the measurement of ion and neutral particle density in this altitude region.

The rocket attained a peak altitude of 159.7 statute miles, approximately 40 statute miles lower than the theoretical prediction. Due to low ceilings radar had intermittent track of the 2nd stage and no track of the 3rd. DOVAP tracked through the complete trajectory. Evidence indicates the 3rd stage went into a flat spin approximately 10 seconds after 3rd stage burnout.

Unfortunately, the thermosphere probe which was to be ejected at T+88 seconds did not eject. This apparently resulted from centrifugal forces caused by the flat spin which prevented the clamshell nose cone from opening to the 165° required to release the probe ejection latch; thus one experiment, the omegatron, was lost. As a result of this malfunction, the dipole antennas on the probe were touching the partially opened clamshell. This resulted in intermittent telemetry signals. The experimental objectives attained, however, were reported to be satisfactory except for the lost omegatron experiment. This rocket provided another first for the Fort Churchill Range by becoming the first Aerobee 300 to be launched by the range under Air Force management. See Figure 56 which shows the prepared rocket, less the nose cone. Figure 57 gives payload dimensions and characteristics of this rocket and its flight.

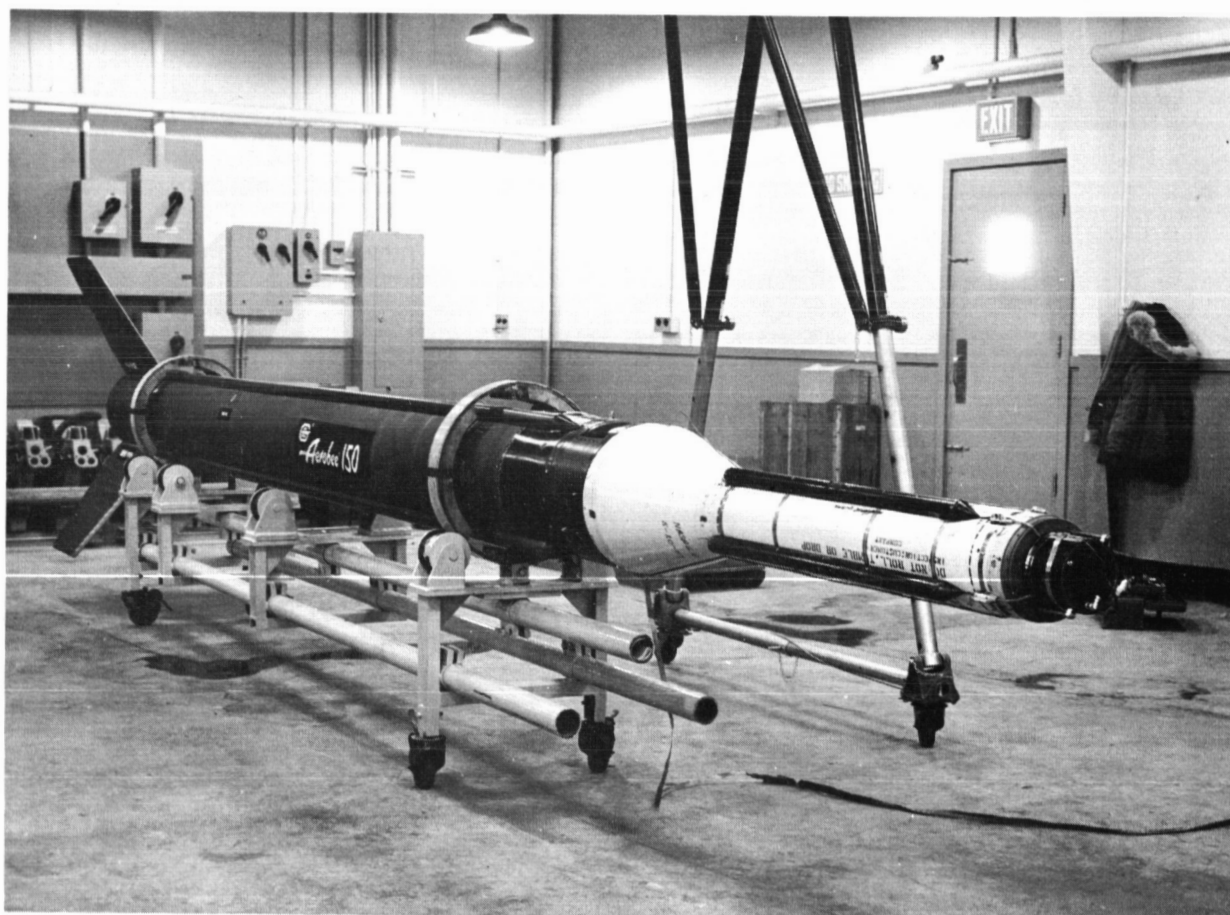
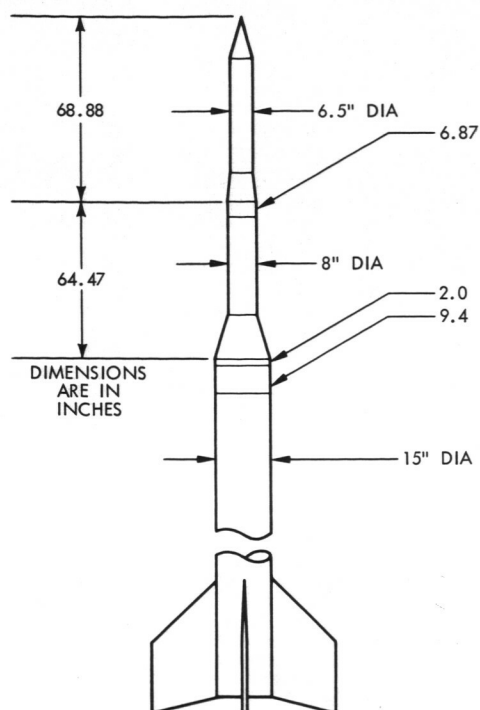


Figure 56. Flight 6.10 GA - Prepared Spaerobee Rocket (Aerobee 300) less Nose Cone



FLIGHT 6.10 GA	
FIRING DATE	28 AUG 1964
LAUNCH SITE	FC
PAYLOAD WEIGHT, 2ND STAGE (lbs)	253.40
APOGEE (statute miles)	200.00
TIME TO APOGEE (seconds)	305.00
CENTER OF GRAVITY, SUSTAINER BURNOUT	10.90
(calculated)	
CENTER OF PRESSURE, SUSTAINER BURNOUT	14.75
(calculated)	
STATIC MARGIN, SUSTAINER BURNOUT	3.85
(calculated)	
RESTORING MOMENT, SUSTAINER BURNOUT	-0.400
(per degree)	
CENTER OF GRAVITY, 3RD STAGE IGNITION	8.38
(calculated)	
CENTER OF PRESSURE, 3RD STAGE IGNITION	11.40
(calculated)	
STATIC MARGIN, 3RD STAGE IGNITION	3.02
(calculated)	
RESTORING MOMENT, 3RD STAGE IGNITION	-0.110
(per degree)	
SUSTAINER BURNOUT (seconds)	54.00
THIRD STAGE BURNOUT (seconds)	*unknown
ROLL RATE AT BURNOUT, SUSTAINER (rps)	2.00
ROLL RATE AT BURNOUT, 3RD STAGE (rps)	*unknown
NUMBER OF JOINTS	8.00
PAYLOAD WEIGHT, 3RD STAGE (lbs)	96.875

*RADAR ONLY PARTIALLY TRACKED SUSTAINER & COULD NOT TRACK 3RD STAGE. T/M LOST COMPLETELY AT T+88 SEC.

Figure 57. Flight 6.10 GA - Dimensions and Flight Characteristics

NASA Flight 4.82 GG

NASA Aerobee 4.82 GG was successfully launched from WSMR on 11 August, carrying four spectrographs to obtain spectra of planets in the region between 1600 to 3000 angstroms. The attitude control system was supposed to point the instruments at Jupiter, Venus and Mars. The rocket attained an apogee of 107 statute miles and although slightly below predicted performance was considered good. The instrumentation rack was located in the nose and a heat shield was utilized to protect the electronics from aerodynamic heating (Figure 59). The ACS was unable to operate, and none of the experimental objectives were met. Upon payload recovery observation of the ACS revealed fragments of gas burst diaphragm material in the despin valve. These fragments prevented the valve from properly seating, thereby allowing the rocket to continue spinning up in a counter-clockwise direction. Chemical analysis confirmed conclusively that the fragments were from the gas line burst diaphragm; Figure 58 shows a photograph of the trapped particles. As a result of this first-time occurrence, a fine-mesh filter has been added in the helium line between the gas burst diaphragm and ACS line in order to trap any diaphragm particles. Figure 60 gives payload dimensions and characteristics of the rocket and its flight.

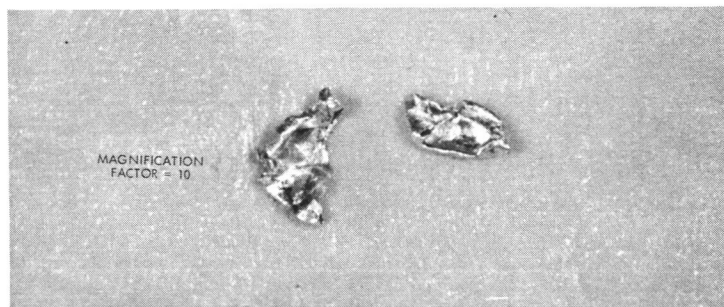


Figure 58. Analysis; Gas Line Burst Diaphragm Fragments

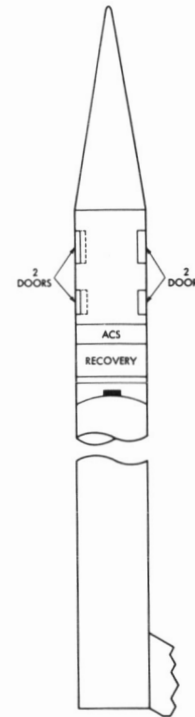
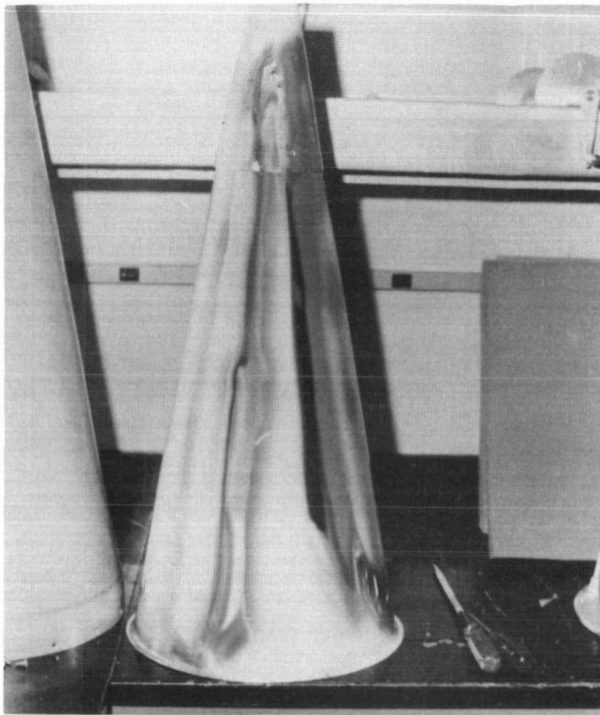
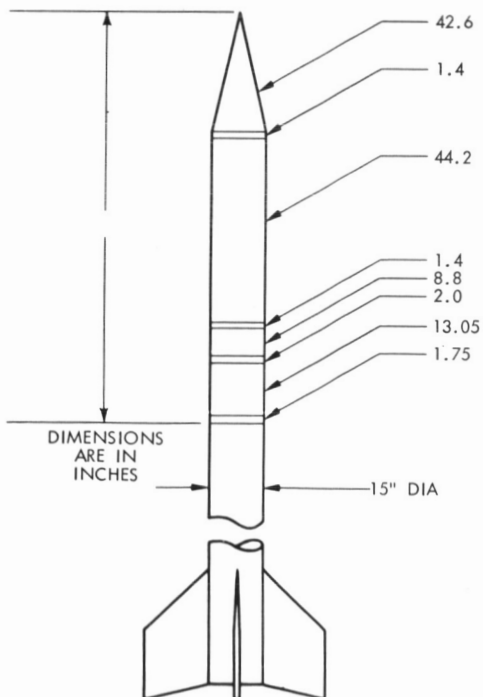


Figure 59. Heat Shield used on Flight 4.82GG



FLIGHT 4.82GG

FIRING DATE	11 AUG 1964
LAUNCH SITE	WSMR
PAYLOAD WT (LBS)	286.00
APOGEE (ST MI)	107.10 (FPS-16)
TIME TO APOGEE (SEC)	221.33 (FPS-16)
CENTER OF GRAVITY (CAL)	9.84
CENTER OF PRESSURE (CAL)	12.35
STATIC MARGIN (CAL)	2.51
RESTORING MOMENT (PER DEGREE)	-0.284
SUSTAINER BURNOUT TIME (SEC)	52.22
ROLL RATE AT BURNOUT (RPS)	2.25 (T/M)
NO. OF JOINTS	8.00

Figure 60. Flight 4.82GG - Dimensions and Flight Characteristics

NASA Flight 4.126 GG

Aerobee 4.126 GG was successfully launched at night from the White Sands range on 22 August. The rocket configuration included four spectrographs which were to obtain ultraviolet spectra data from Mars, Venus and Jupiter, after being pointed by the attitude control system. This flight required a pre-morning twilight launch.

Prior to launching the rocket, the tail can was strengthened by the addition of a magnesium liner which was riveted in place with 200 flush head rivets. The only pre-launch difficulty was experienced prior to lift off. The overboard dump valve squib leads were broken and could not be replaced in the tower due to the excess amount of instrumentation in the forward skirt. The valve was closed manually however prior to installation of the forward skirt door. The new filter was added to the helium line in the regulator to trap gas burst diaphragm fragments (discussed in 4.82 GG). Rocket performance appeared normal until T+46 seconds except for a slightly lower than expected thrust chamber pressure (Figure 61). Starting at T+46 seconds erratic thrust chamber pressures were observed (Figure 61) and burnout occurred several seconds earlier than expected.

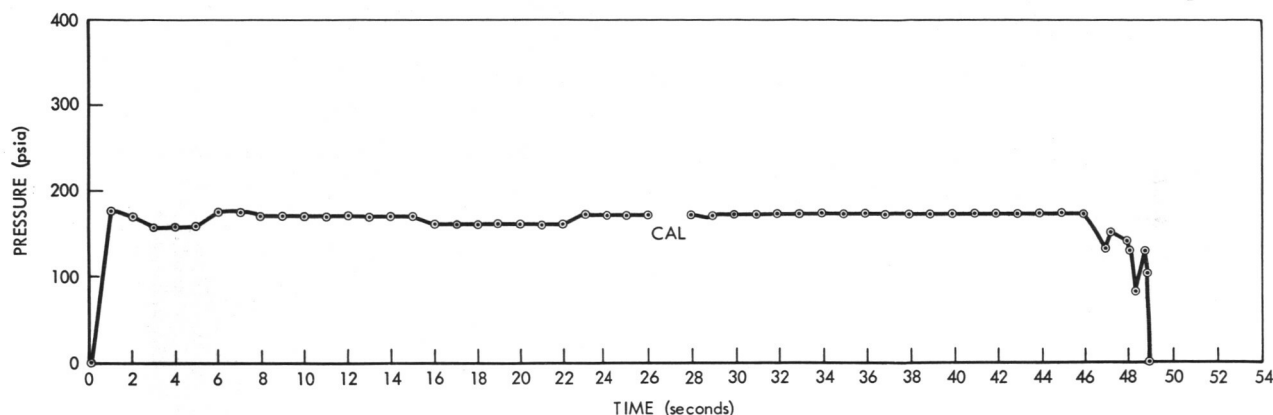


Figure 61. Flight 4.126 GG - Chamber Pressure vs Time

Post-flight inspection of the thrust chamber verified hypotheses that a chamber "burn-through" had occurred. Figure 62 shows the thrust chamber for this flight after it had been returned and inspected at GSFC. The burn through which occurred can easily be seen. This figure, a discussion of the burn through problem and photographs of other similar occurrences is the subject of Reference 4. There was positive evidence that the inner liner had burned through at the convergent section of the thrust chamber. Peak altitude was 77 statute miles, 45 miles short of predicted. The rocket's performance was continuously monitored throughout the flight by an accelerometer (Figure 63) and a thrust chamber pressure gauge. Onboard telemetry also monitored the pitch movements of the rocket (See Figure 64).

During flight the ACS performed as expected. Although the lower than predicted peak altitude shortened the time available for experimental observation, sufficient scientific data was obtained. Thus the lower than expected altitude did not seriously compromise the experimental objectives.

The standard recovery system was successfully used in effecting a quick payload recovery. The sustainer was recovered. Figure 65 gives payload dimensions and characteristics of this rocket and its flight.



Figure 62. Flight 4.126 GG - Thrust Chamber Burn Through

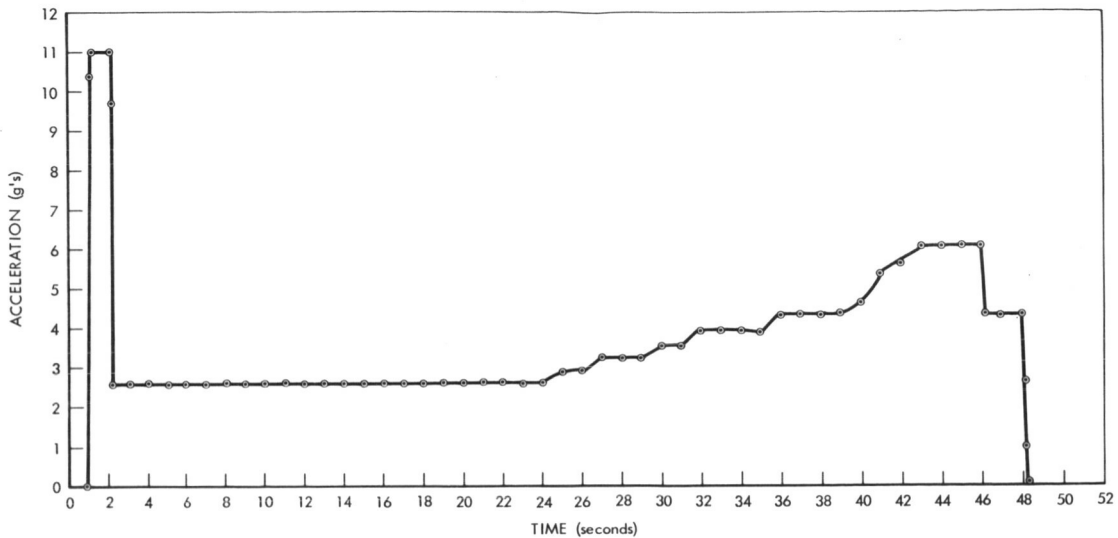


Figure 63. Flight 4.126 GG - Acceleration vs Time

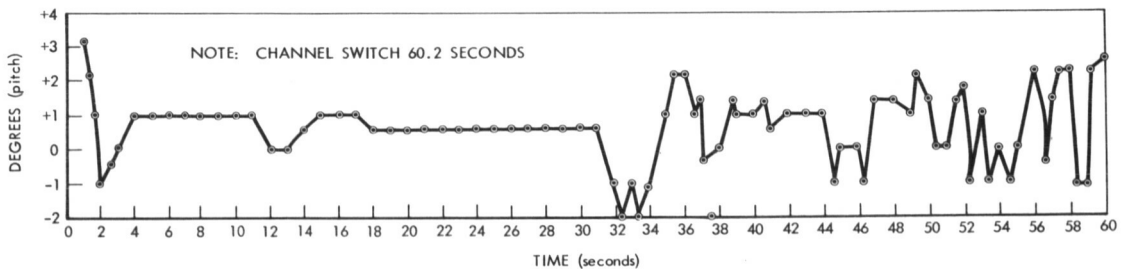
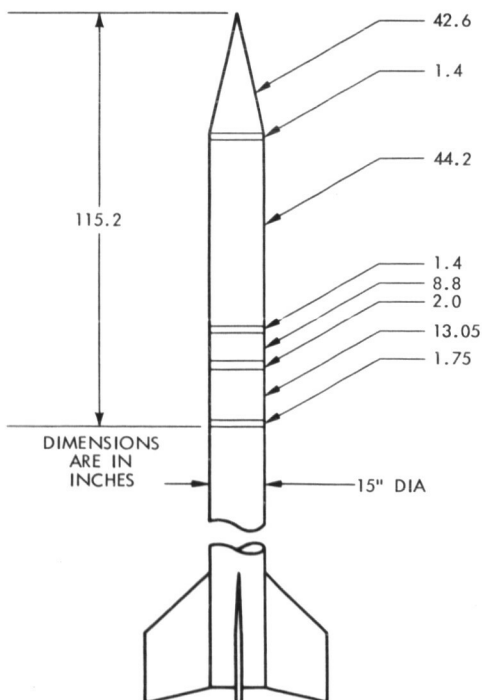


Figure 64. Flight 4.126 GG - Pitch vs Time



FLIGHT 4.126 GG

FIRING DATE	22 AUG 1964
LAUNCH SITE	WSMR
PAYLOAD WT (LBS)	265.625
APOGEE (ST MI)	76.60 (PB)
TIME TO APOGEE (SEC)	190.00
CENTER OF GRAVITY (CAL)	9.81
CENTER OF PRESSURE (CAL)	12.50
STATIC MARGIN (CAL)	2.72
RESTORING MOMENT (PER DEGREE)	-0.278
SUSTAINER BURNOUT TIME (SEC)	48.68 (T/M)
ROLL RATE AT BURNOUT (RPS)	1.90 (T/M)
NO. OF JOINTS	8.00

Figure 65. Flight 4.126 GG - Dimensions and Flight Characteristics

NASA Flight 4.122 CG

NASA rocket 4.122 CG was launched successfully to a peak altitude of 110 statute miles from WSMR on 29 August. The primary scientific objectives were to collect data on the size, location and flux levels of celestial X-ray sources. Experimental instrumentation included 4 banks of Gieger counters (Figure 66), a photoelectric detector, two scintillation counters, and a star sensor. A fiberglass ogive nose cone, modified for ejection of 3 doors (subsequent to burnout), was used.

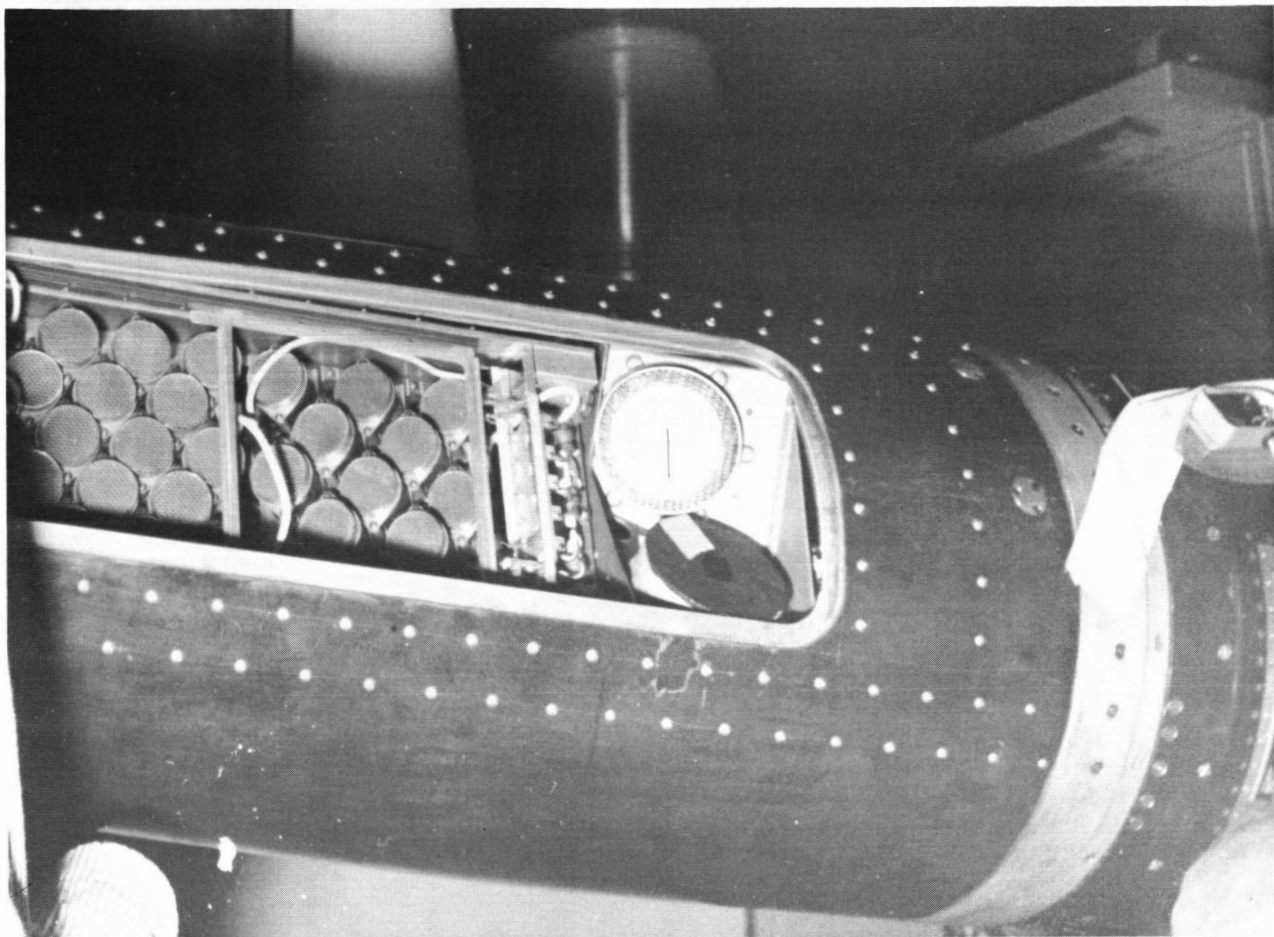


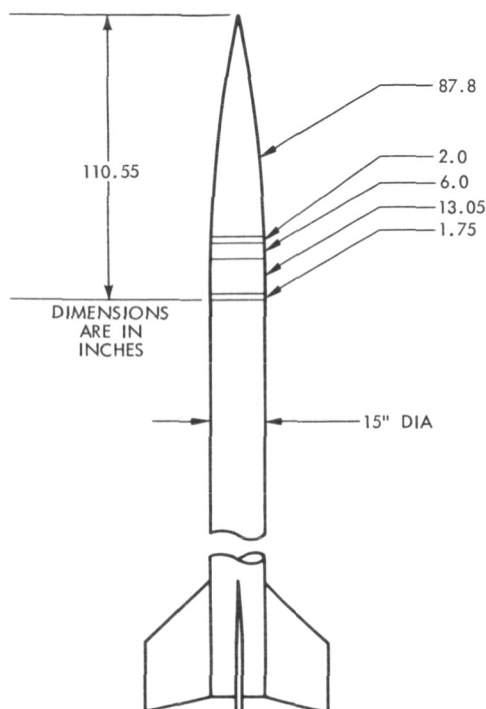
Figure 66. Flight 4.122 CG - Payload

Vehicle launch operation was normal and no performance anomalies were observed. Burnout velocity was lower than predicted, and apogee attained was consequently 20 miles below predicted. The roll rate at burnout was 1.1 rps.

Despite the lower than anticipated peak altitude attained, the experiment functioned properly and good data was collected. The experiment was reportedly 85% successful.

The recovery system functioned as planned, and the payload was successfully recovered. The sustainer was also recovered. A close inspection was made of the recovered thrust chamber but no abnormal conditions were observed to account for the large altitude under performance.

Figure 67 gives payload dimensions and characteristics of this rocket and its flight.



FLIGHT 4.122 CG

FIRING DATE	29 AUG 1964
LAUNCH SITE	WSMR
PAYLOAD WT (LBS)	264.125
APOGEE (ST MI)	111.20
TIME TO APOGEE (SEC)	225.70
CENTER OF GRAVITY (CAL)	10.00
CENTER OF PRESSURE (CAL)	13.20
STATIC MARGIN (CAL)	3.20
RESTORING MOMENT (PER DEGREE)	-0.336
SUSTAINER BURNOUT TIME (SEC)	52.00
ROLL RATE AT BURNOUT (RPS)	1.10
NO. OF JOINTS	5.00

Figure 67. Flight 4.122 CG - Dimensions and Flight Characteristics

NASA Flight 4.55 UG

On 2 September NASA vehicle 4.55 UG was successfully launched from Wallops Island to a peak altitude of 96.5 statute miles. Although the altitude performance was expectedly less than predicted, all rocket and experimental instrumentation functioned well and good quality data was received.

The propulsion system was monitored by a thrust chamber pressure transducer (Figure 68) and an accelerometer (Figure 69). Nose cone pressure was also monitored during flight to determine if there was any outgassing. Two magnetometers were used for providing aspect data. A 14.2" diameter cone cylinder nose cone was used rather than the standard Aerobee ogive nose cone; this was adapted to the 15" vehicle diameter by a transition extension.

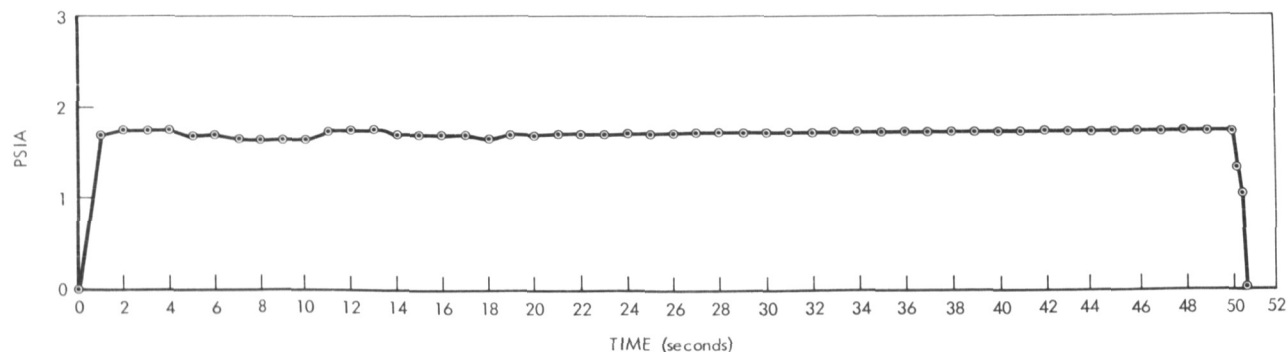


Figure 68. Flight 4.55 UG - Chamber Pressure vs Time

At approximately 68 seconds of flight, the standard gas operated despin system (mounted in the regulator section of the sustainer) was activated. Twenty-seven seconds were required to

despin the rocket down to 0.04 rps. This contributed to the desirable precessional half angle of approximately 45° . The roll rate prior to despin was indicated by the magnetometer to be 2.5 rps. No ACS system or recovery package was required for the flight. The telemetry system provided good data for 387 seconds and all instrumentation functioned as expected. Despite the lower than predicted apogee, excellent experimental data was reportedly obtained.

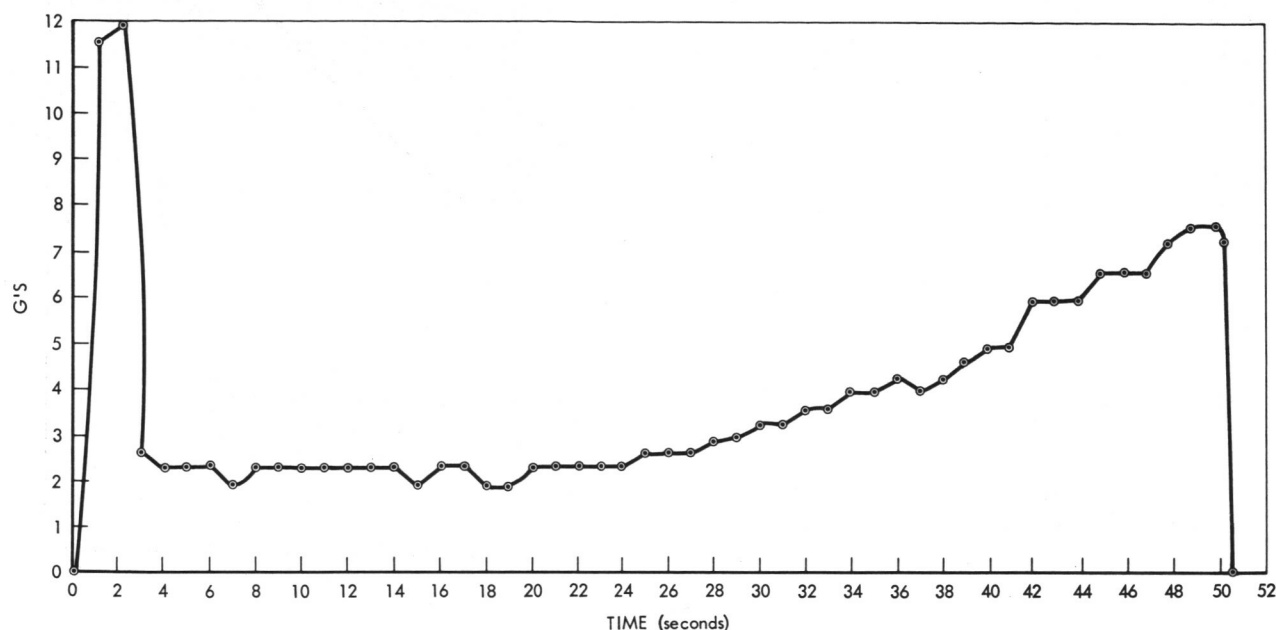


Figure 69. Flight 4.55UG - Acceleration vs Time

The purpose of the experiment was to measure the brightness of stars in the ultraviolet spectral bands peaked at 2800 \AA , 2500 \AA and 2100 \AA . Instrumentation used for these measurements included two sets of four photoelectric photometers with filters. Eight windows were cut in the nose cone to permit experimental telescopes whose axis were perpendicular to the vehicle axis to "look out" during the flight. Figure 70 shows these photometers.

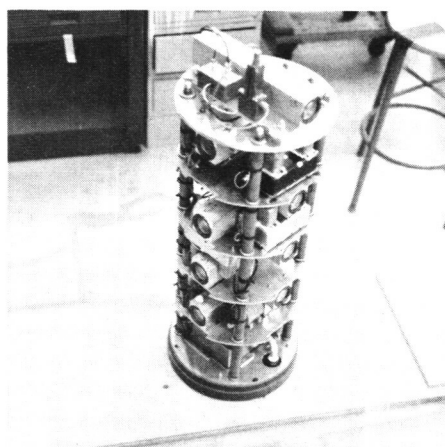
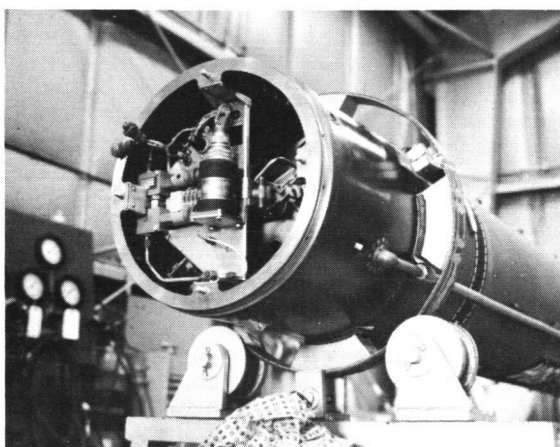


Figure 70. Flight 4.55UG - Photometers used on Payload

Burnout velocity for NASA 4.55 UG was predicted to be 5700 ft/sec; burnout statistics indicated a burnout velocity of 5180 ft/sec at 106,000 feet. Figure 71 shows the altitude plot for the first 62 seconds of flight.

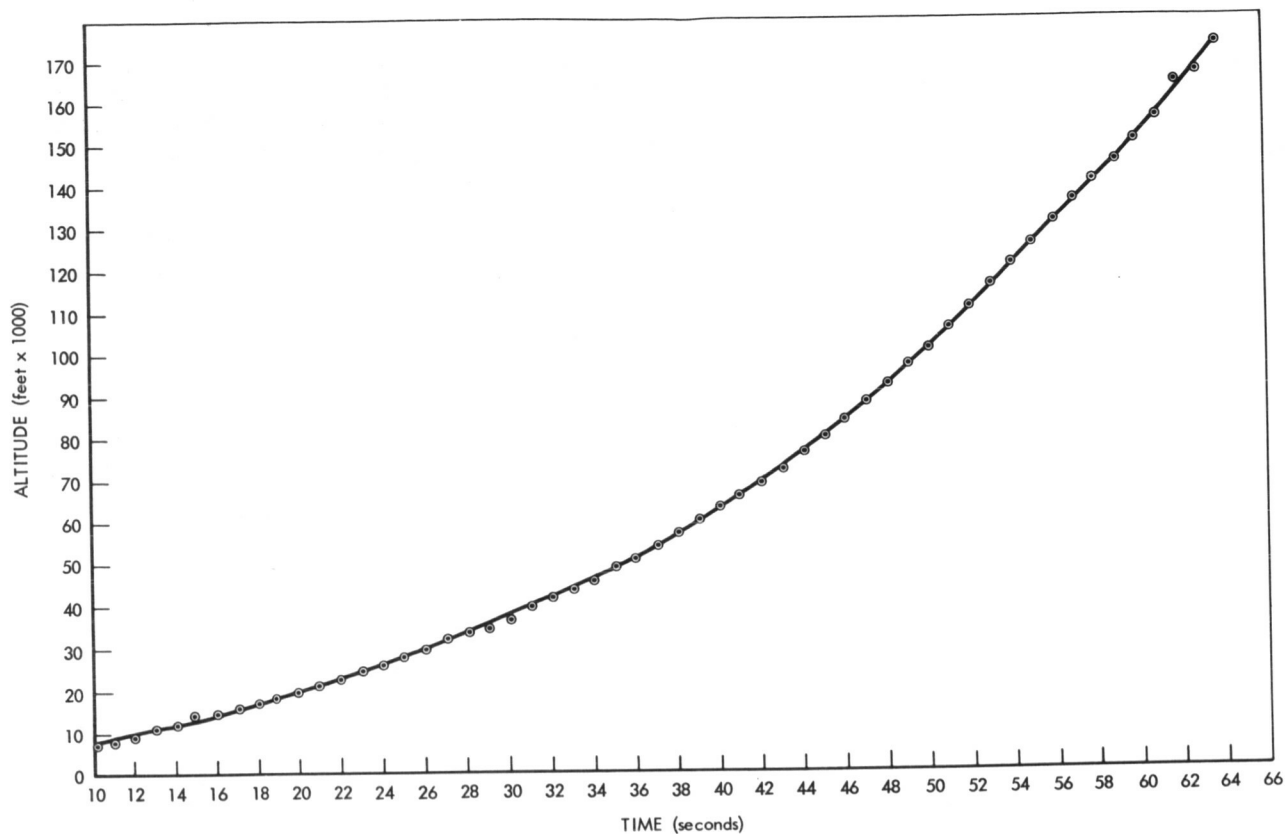
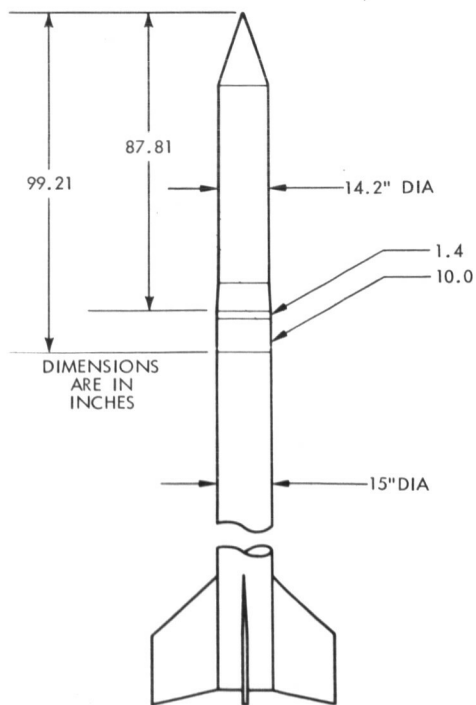


Figure 71. Flight 4.55UG - Altitude vs Time

Figure 72 gives payload dimensions and characteristics of this rocket and its flight.



FLIGHT 4.55UG

FIRING DATE	2 SEPT 1964
LAUNCH SITE	WI
PAYLOAD WT (LBS)	219.80
APOGEE (ST MI)	97.10
TIME TO APOGEE (SEC)	215.10
CENTER OF GRAVITY (CAL)	9.34
CENTER OF PRESSURE (CAL)	12.32
STATIC MARGIN (CAL)	2.98
RESTORING MOMENT (PER DEGREE)	-0.410
SUSTAINER BURNOUT TIME (SEC)	51.70
ROLL RATE AT BURNOUT (RPS)	2.50
NO. OF JOINTS	4.00

Figure 72. Flight 4.55UG - Dimensions and Flight Characteristics

NASA Flight 4.115 NA

NASA 4.115 NA was successfully launched from Wallops Island on 18 September. The vehicle displayed satisfactory performance, reaching a peak altitude of 105 statute miles. No unusual anomalies were observed on this flight which was similar in experimental objectives to NASA flight 4.86 NA, but without a recovery system. The successful performance of this rocket illustrates a typical Wallops Island Cone Cylinder Aerobee rocket behavior.

The purpose of the experiment was to measure ultraviolet light emitted from the sun and scattered by the earth's atmosphere (dayglow). An additional objective was to measure the earth's albedo in the wave length spectral range of 1100-3300 Å. By using the standard Attitude Control System (ACS), the payload was first pointed in a zenith position for measurement. At 229 seconds, the rocket was programmed to turn over and look downwards to measure the earth's albedo; the vehicle was then pointed-programmed to pitch up to zenith. On the downward leg the rocket was pointed at the horizon.

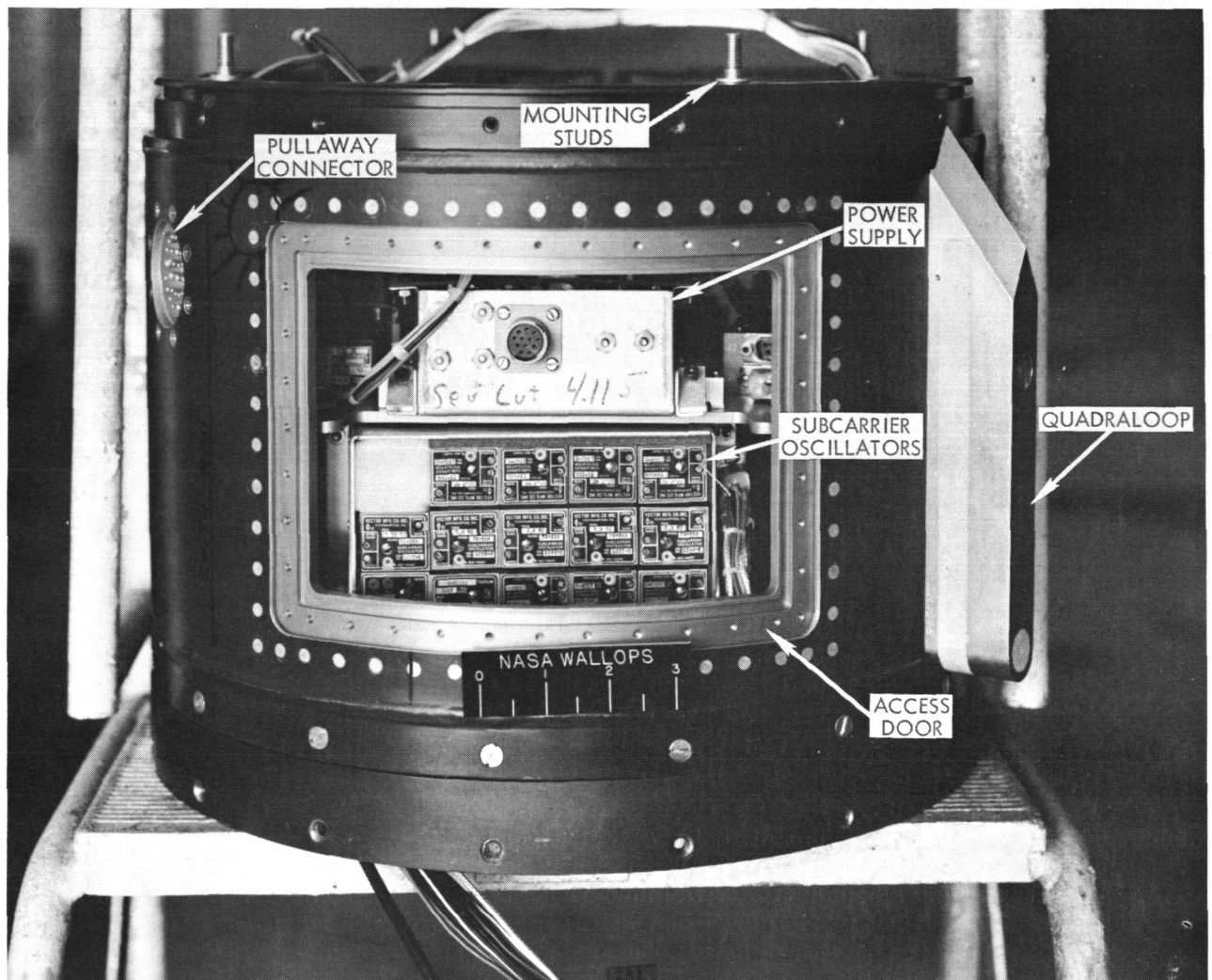


Figure 73. Flight 4.115 NA - Telemetry Can

The nose cone configuration consisted of a modified cone cylinder, designed to eject the forward tip at 63 seconds. The fins were set for a roll rate of 2.5 rev/sec at sustainer burnout.

Sustainer burnout occurred at 114,000 feet at a velocity of 5316 ft/sec; these parameters were very close to predicted estimates for the flight. Figure 74 shows the chamber pressure, regulated helium pressure and oxidizer tank pressures observed during the flight. Figure 75 provides acceleration information.

Good experimental data was continuously received throughout the flight for 450 seconds. No recovery system was required for the flight.

Figure 76 gives payload dimensions and characteristics of this rocket and its flight.

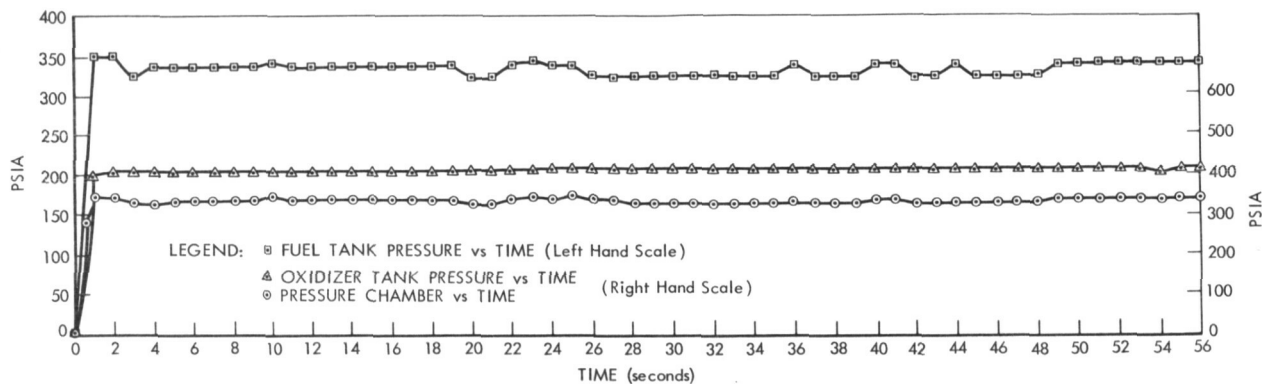


Figure 74. Flight 4.115 NA - Chamber Pressure, Fuel Pressure, and Oxidizer Pressure vs Time

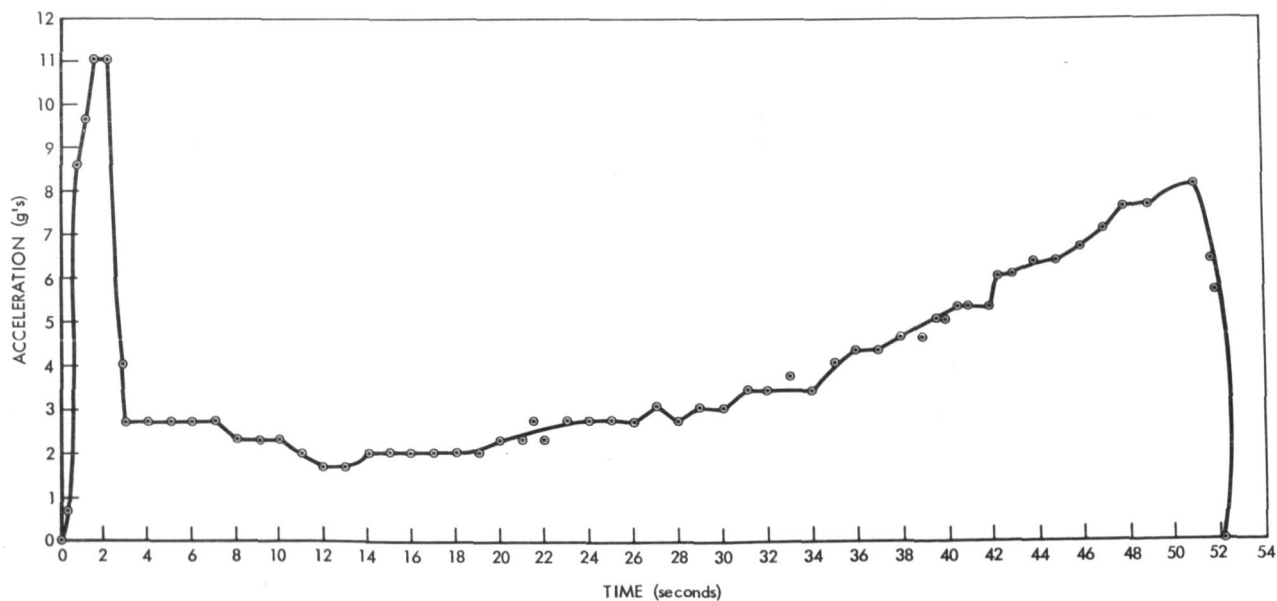
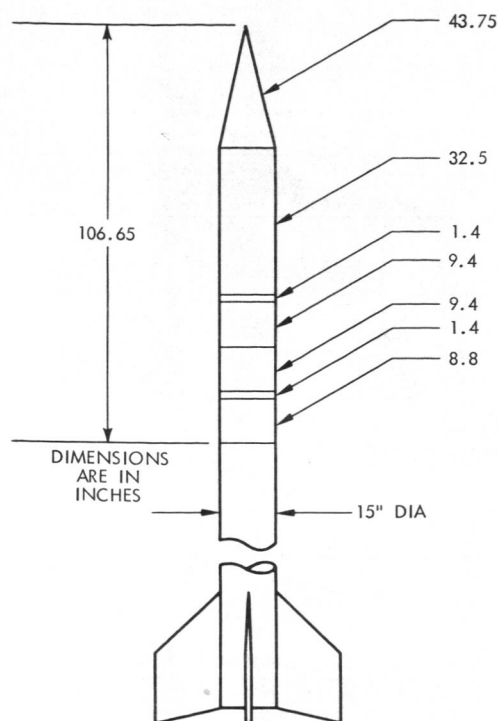


Figure 75. Flight 4.115 NA - Acceleration vs Time



FLIGHT 4.115 NA		
FIRING DATE		18 SEPT 1964
LAUNCH SITE		WI
PAYLOAD WT (LBS)		240.00
APOGEE (ST MI)		104.40
TIME TO APOGEE (SEC)		222.10
CENTER OF GRAVITY (CAL)		9.67
CENTER OF PRESSURE (CAL)		12.72
STATIC MARGIN (CAL)		2.96
RESTORING MOMENT (PER DEGREE)		-0.407
SUSTAINER BURNOUT TIME (SEC)		52.20
ROLL RATE AT BURNOUT (RPS)		
TIP EJECT (SEC)		~63.00
NO. OF JOINTS		7.00

Figure 76. Flight 4.115 NA - Dimensions and Flight Characteristics

NASA Flight 4.13 GP-GT

On 26 September 4.13 GP-GT was successfully fired from Wallops Island; the primary purpose of the instrumentation was to obtain quantitative propulsion and environmental data in order to solve the consistent 150 A underperformance problem. Several other experiments were also flown and included: the testing of a new GSFC designed and fabricated attitude control system; the measurement of low energy gamma rays; the measurement of sodium vapor radiation in the upper atmosphere; the evaluation of a new DOVAP transmitter; the study of nuclear emulsions to be used in cosmic ray studies; and the attempt to recover the sustainer and portions of the payload for post flight evaluation and eventual reflight of the vehicle.

This flight was significant in that it has substantially advanced the knowledge of the Aerobee 150 A propulsion system and has been instrumental in solving the underperformance problem.

NASA 4.13 GP-GT configuration used a conical nose cone which was designed for ejection at T+75 seconds during flight. Peak altitude for the 342 lb net payload was 74.5 statute miles; pre-flight calculations indicated a peak altitude of 85.7 miles. Burnout occurred early at 50.8 seconds, and it has been theorized that oxidizer depletion was the reason for the short burning time and the less-than-predicted apogee. This has been corrected in later flights by decreasing the oxidizer flow rate and it has resulted in approaching vehicle performance design parameters.

Figure 77 shows the assembled rocket during DOVAP antenna tuning and prior to installation in the tower. Figure 78a shows the tailcan section which was filled with pressure transducers and power amplifiers. An attempt was made at vehicle recovery by severing at Station 72.5. This would have allowed recovery, too, of onboard instrumentation aft of Station 72.5. Figure 78b shows the explosive bolts which were used to sever the tail fins. The recovery sequence was to be as follows:

- (1) The barometric actuation box should be armed on the upward leg of the trajectory.

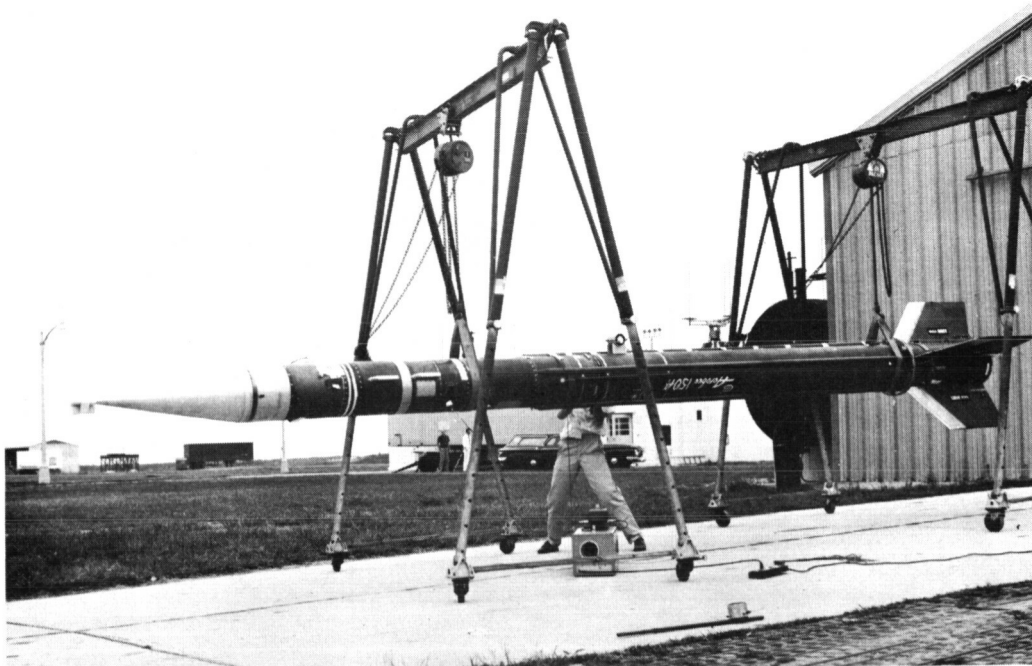


Figure 77. Flight 4.13GP-GT - Assembled Rocket for DOVAP Antenna Tuning

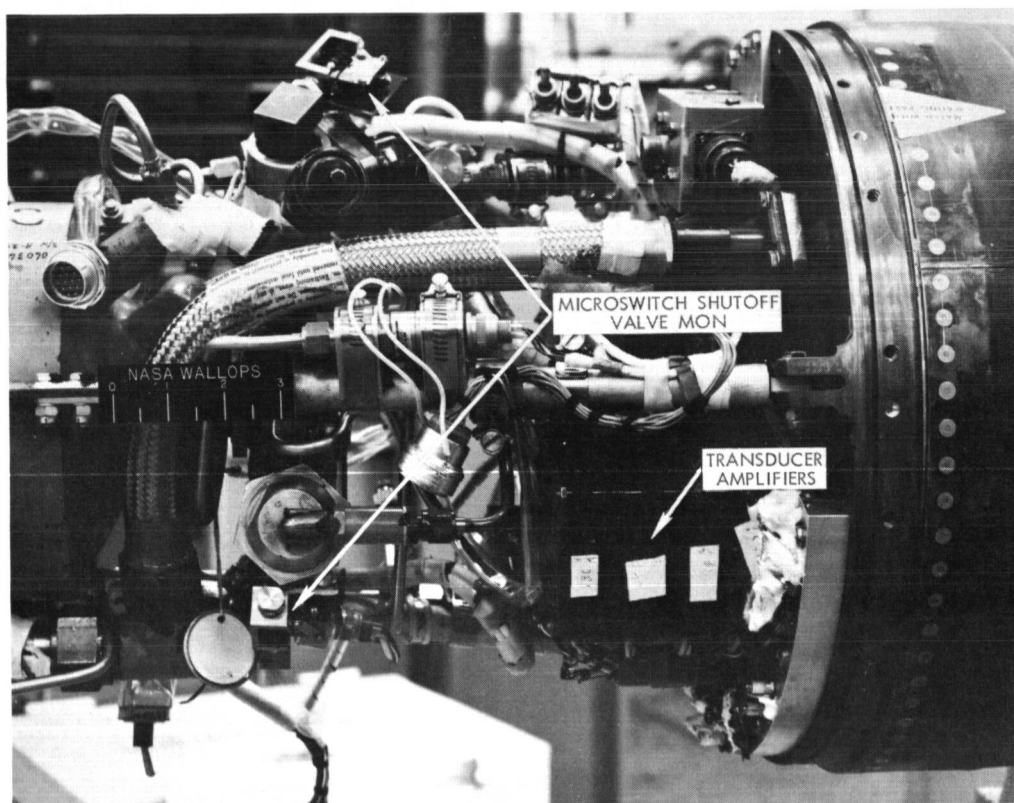


Figure 78a. Flight 4.13GP-GT - Tail Section with Performance Instrumentation

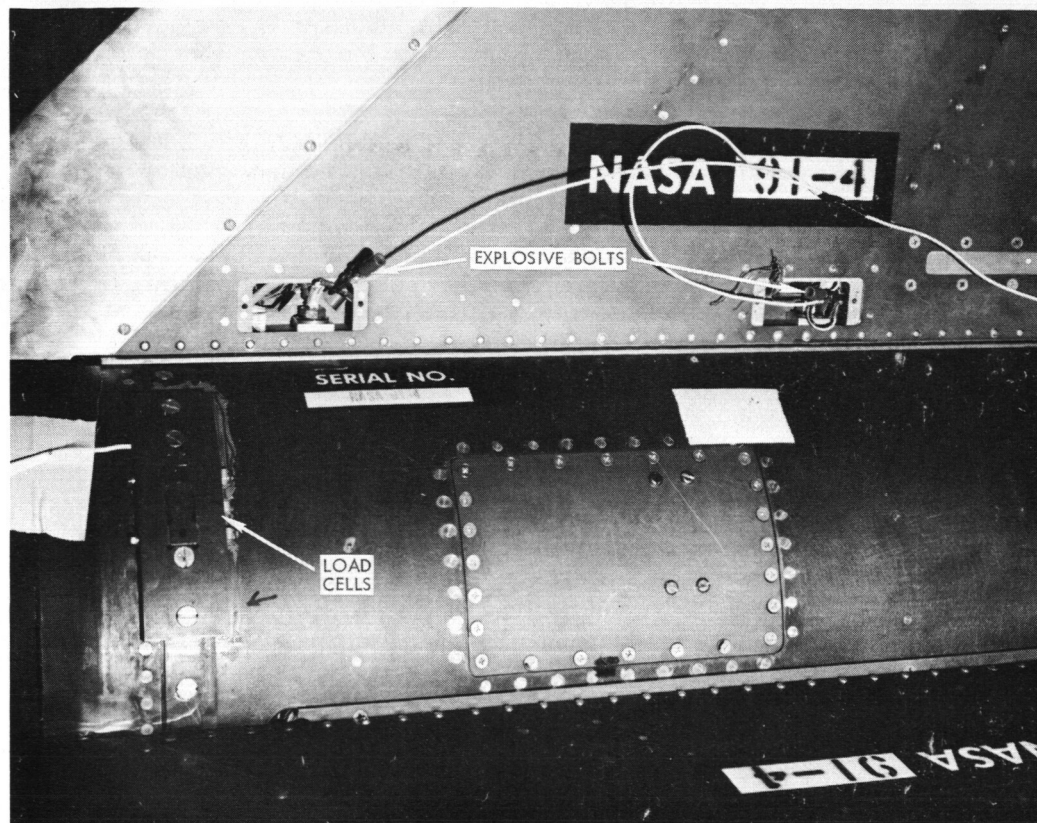


Figure 78b. Flight 4.13GP-GT - Tail Section

- (2) During the downward leg of the trajectory, at approximately 200,000 feet, the fins and the payload should be severed from the rocket either by command or timer signal.
- (3) The sustainer should establish a flat spin, free falling mode. This attitude should reduce its velocity as it re-enters the atmosphere until a terminal velocity of approximately 250 to 300 fps is reached.
- (4) At approximately 20,000 feet altitude, the barometric actuation box should initiate second severance.
- (5) Upon severance, the recovery system extension cover should separate and become ejected into the airstream where its aerodynamic drag extracts the reefed FIST ribbon drogue-pilot parachute deployment bag and bridle.
- (6) The drogue-pilot parachute should inflate to its reefed shape, its drag force initiating the main parachute deployment bag's reefing line cutters. Stabilization and pitch-up of the sustainer would be initiated by the reefed drogue-pilot parachute.
- (7) After three (3) seconds, the FIST ribbon drogue-pilot parachute should disreef and open fully, thus further stabilizing and decelerating the sustainer.
- (8) The sustainer should then fall in a stable, tail-first position, for approximately nine (9) more seconds, at which time the main parachute deployment bag's reefing cutter system would be activated causing deployment of the main parachute by the drogue-pilot parachute.

(9) The main parachute should open and decelerate the sustainer to a velocity of approximately 30 fps at water impact. The sustainer would thus impact into the water, where it will float due to its own buoyancy. Once located, it can be retrieved.

Figures 80 through 83 summarize the pressure transducer outputs which all indicated that no unexpected pressure drops occurred during flight to account for the underperformances in peak altitude that has consistently been indicative of 150 A flights.

Figure 84 is the booster pressure trace which was also measured during the 2.5 seconds of booster burning. Figure 85 gives payload dimensions and characteristics of this rocket and its flight.

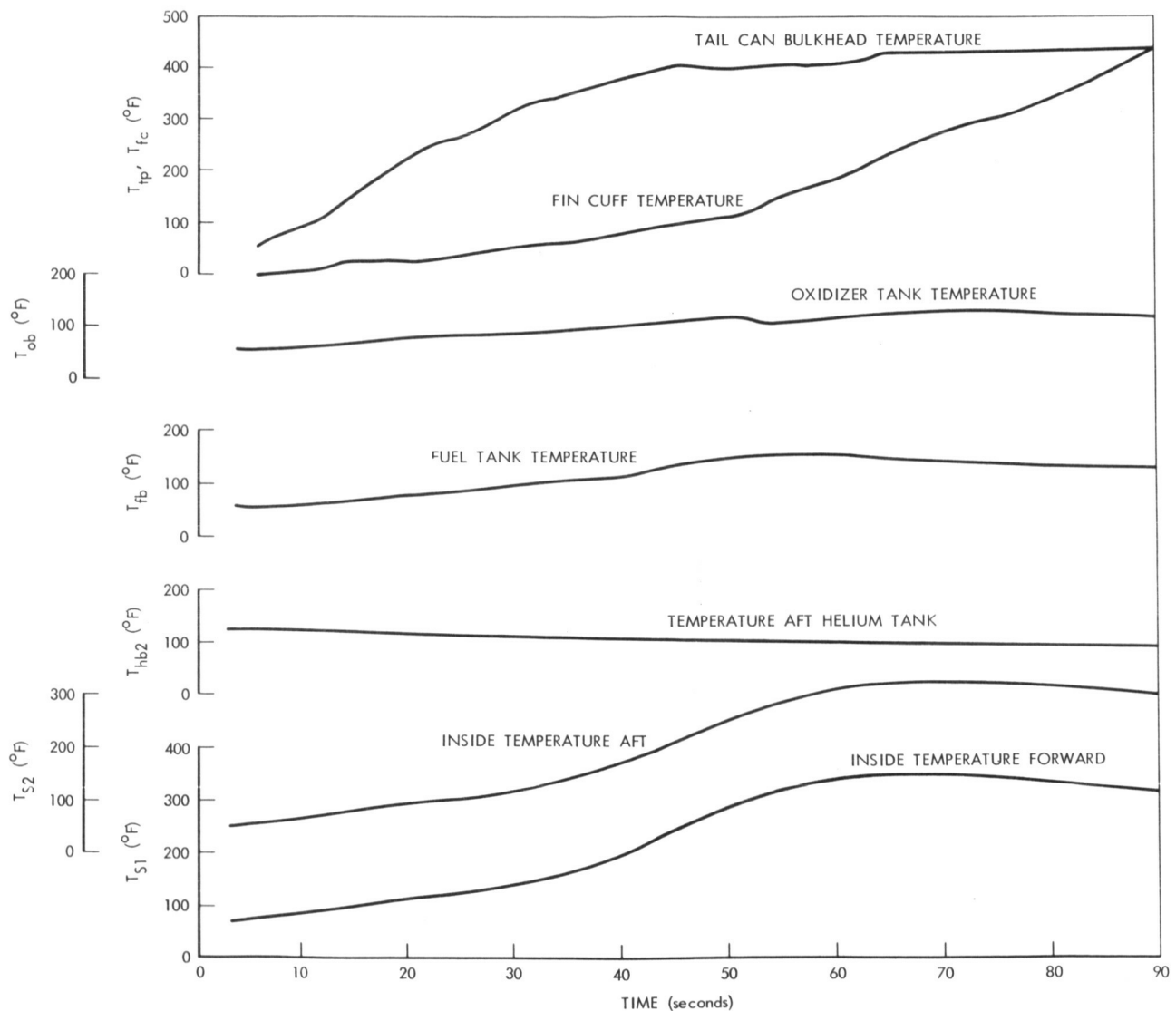


Figure 79. Flight 4.13GP-GT - Temperature vs Time

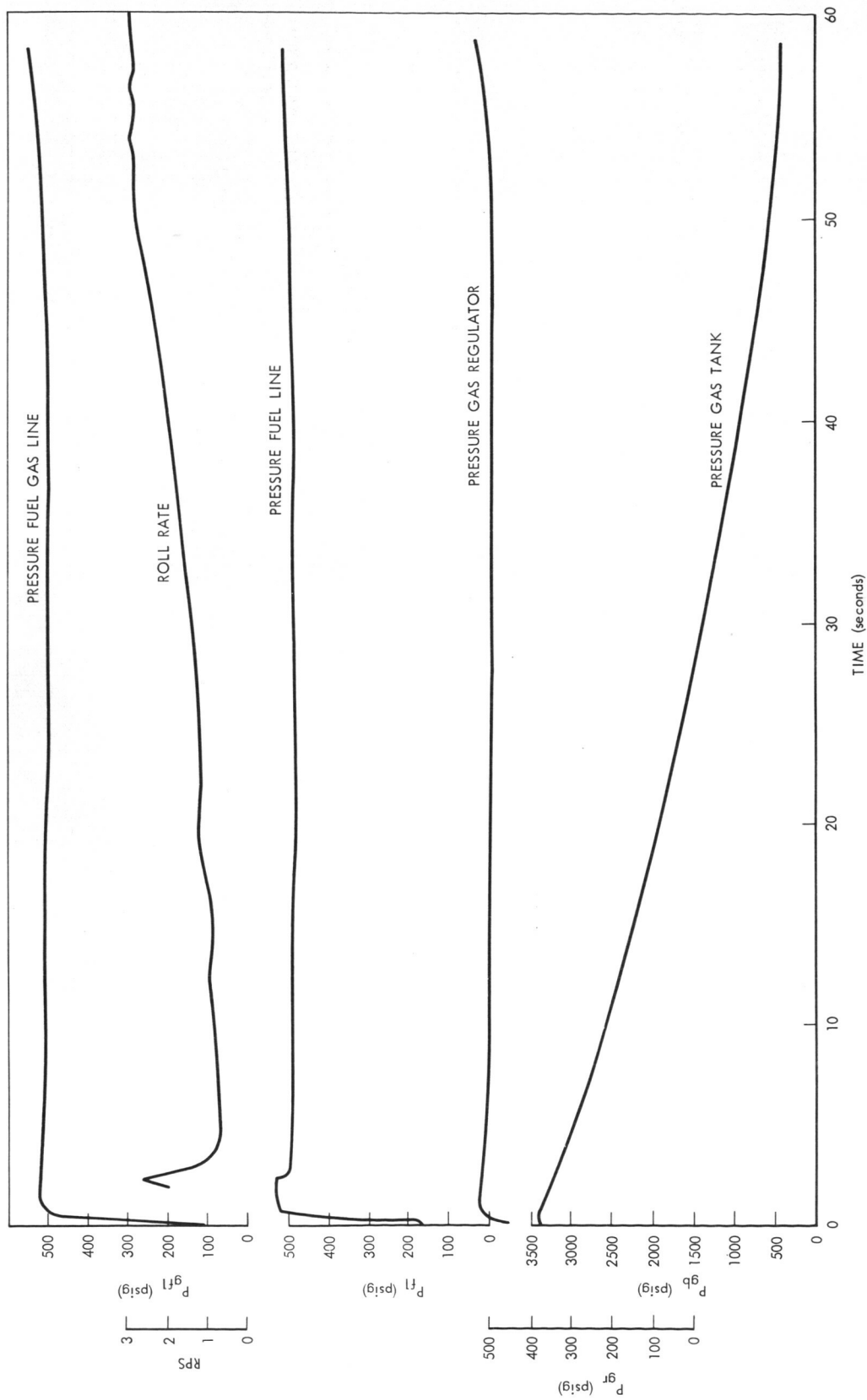


Figure 80. Flight 4.13 GP-GT - Pressure vs Time

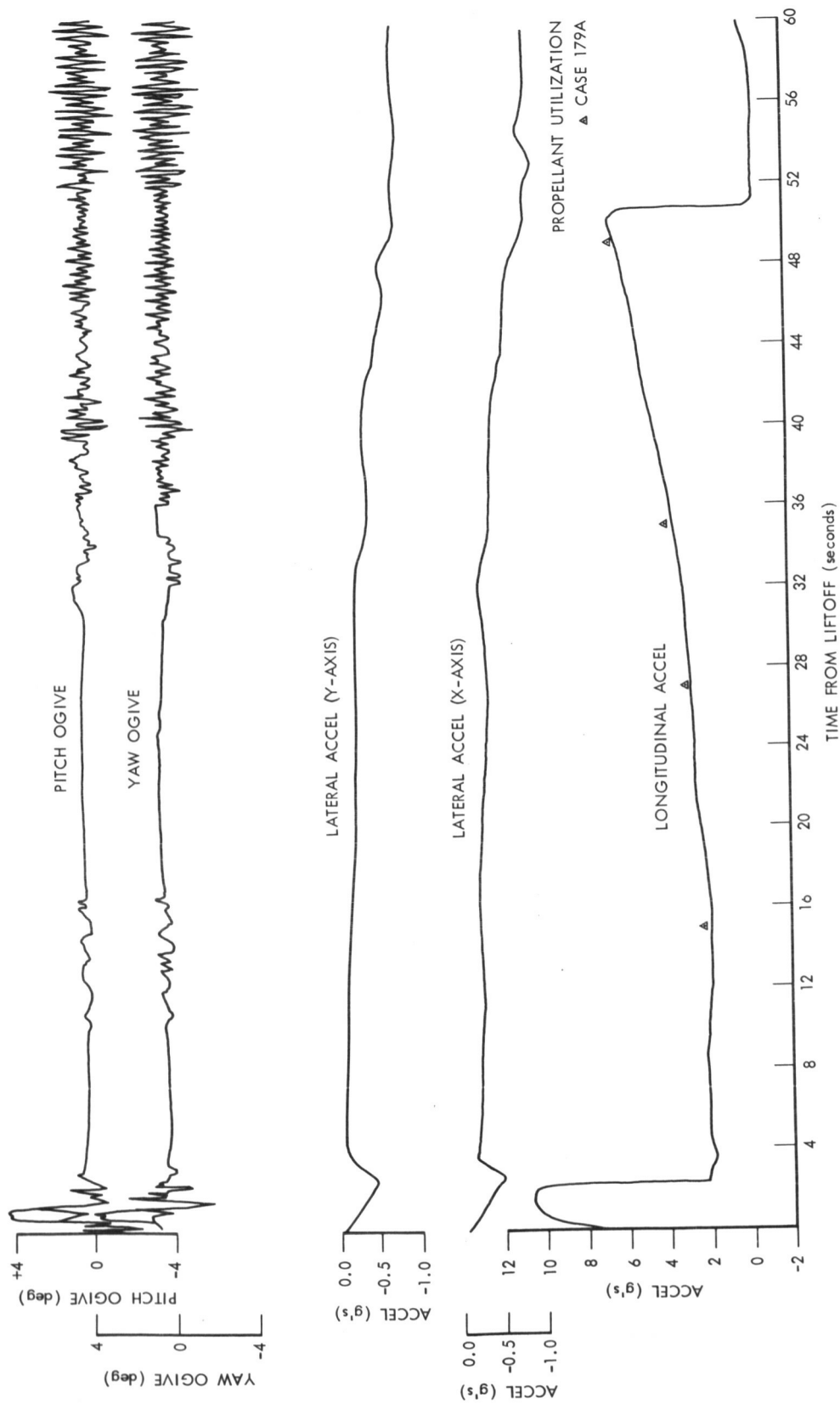


Figure 81. Flight 4.13GP-GT - Pitch Ogive, Yaw Ogive, and Acceleration vs Time from Lift-off

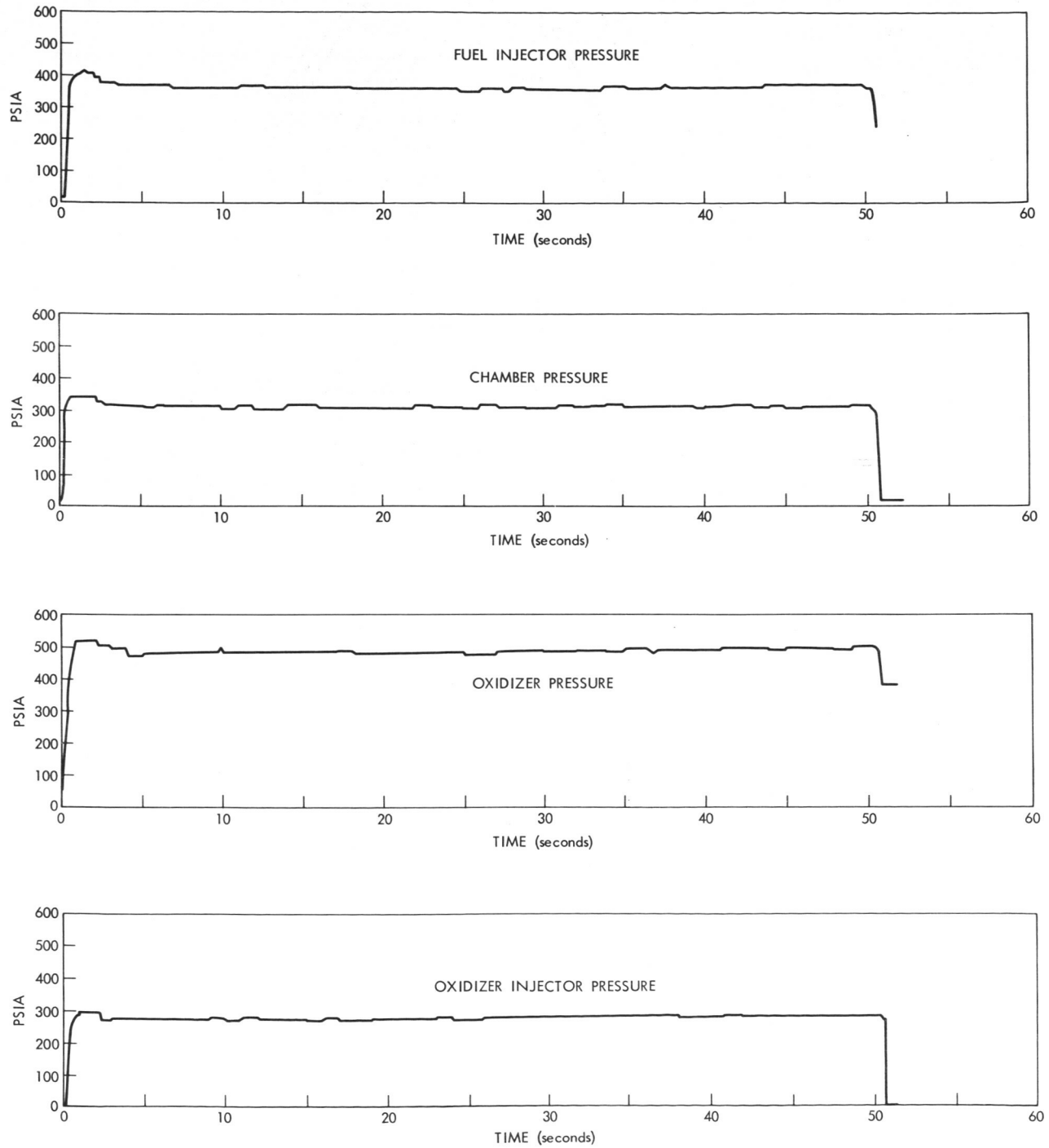


Figure 82. Flight 4.13 GP-GT - Fuel, Oxidizer and Chamber Pressure vs Time

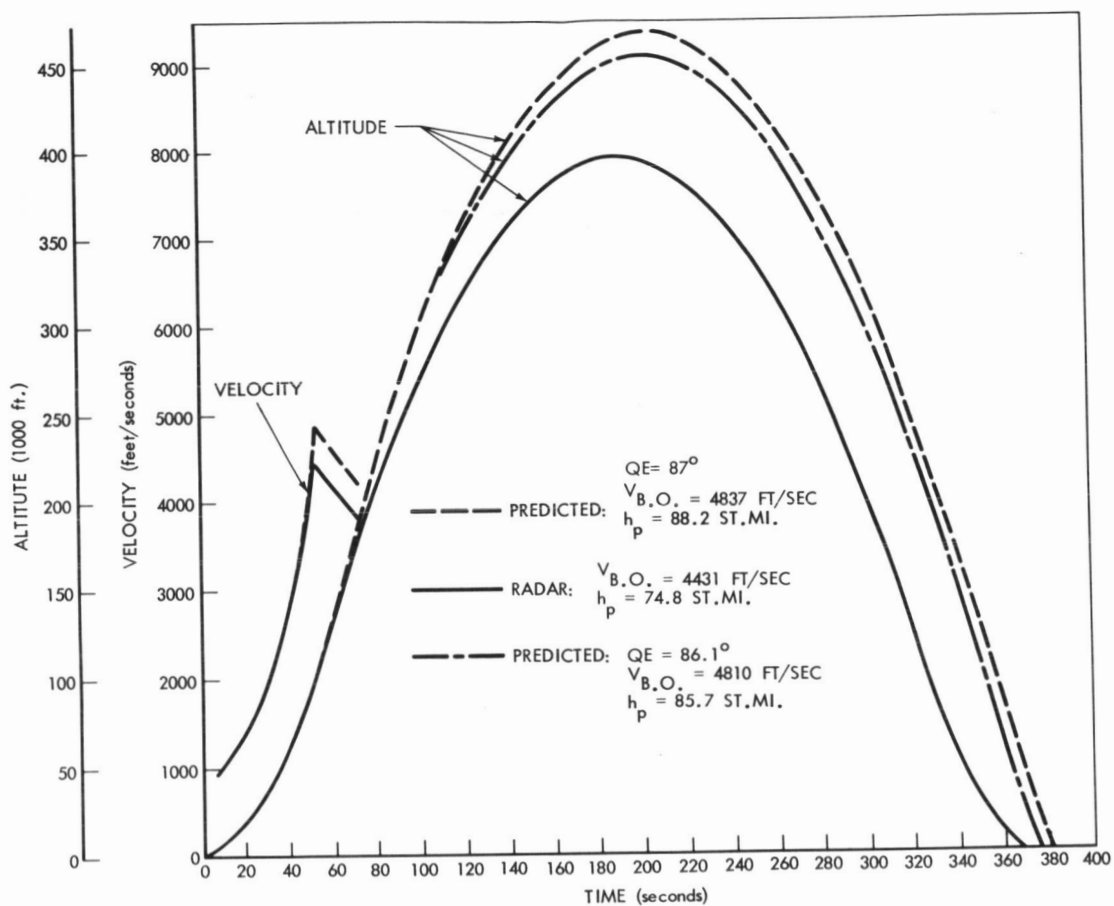


Figure 83. Flight 4.13GP-GT - Velocity and Altitude vs Time

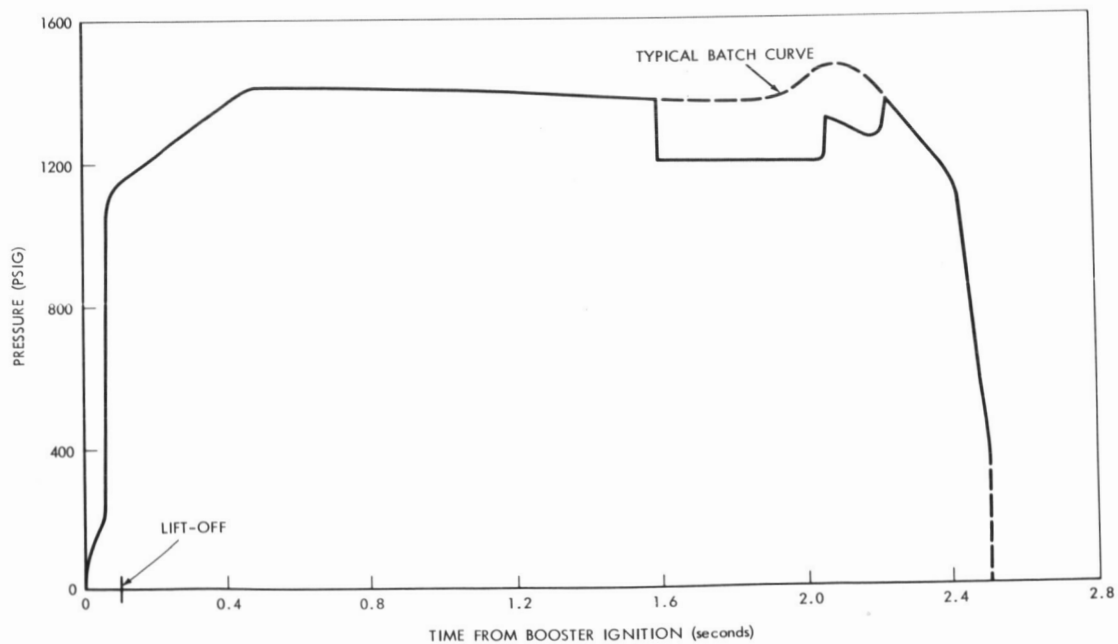
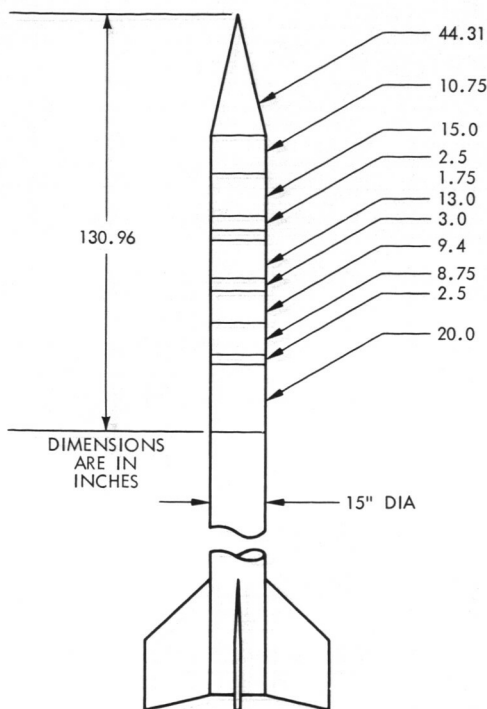


Figure 84. Flight 4.13GP-GT - Booster Pressure vs Time from Booster Ignition



NASA Flight 4.120 CG

NASA vehicle 4.120 CG successfully lifted a 356.9 lb net payload weight to a peak altitude of 89 statute miles from the White Sands Missile Range on 2 October. The payload (See Figure 86) was intended for surveying night sky sources which emit photons in the 0.6 to 20.0 keV energy region. The experiment consisted of special gas filled counters which were used to obtain measurements of the detected X-rays and three photometers. The standard Attitude Control System was used; after erecting to the roll, pitch and yaw gyros the rocket was pitched so that its horizontal axis was approximately horizontal and pointing toward the southeast. The experiment required a scanning mode so the vehicle was yawed to the northeast horizon and to the southwest horizon and back. The 3-wrap yo-yo despin system did not function due to an improper connection between the squib pin puller and electrical connectors which prevented power from reaching the squib. However the gas despin system, which was in parallel with the yo-yo, despun the vehicle thereby not affecting the ACS performance.

Vehicle performance was as expected; the sustainer burned out at 108 K feet traveling 4650 ft/sec. The standard recovery package functioned as expected and payload retrieval was quickly effected.

FLIGHT 4.13GPGI

FIRING DATE	27 SEPT 1964
LAUNCH SITE	WI
PAYLOAD WT (LBS)	341.80
APOGEE (ST MI)	74.50
TIME TO APOGEE (SEC)	203.80
CENTER OF GRAVITY (CAL)	11.06
CENTER OF PRESSURE (CAL)	14.21
STATIC MARGIN (CAL)	3.15
RESTORING MOMENT (PER DEGREE)	-0.53
SUSTAINER BURNOUT TIME (SEC)	51.10
ROLL RATE AT BURNOUT (RPS)	2.10
TIP EJECT (SEC)	~68.00
NO. OF JOINTS	11.00

Figure 85. Flight 4.13GP-GT - Dimensions and Flight Characteristics

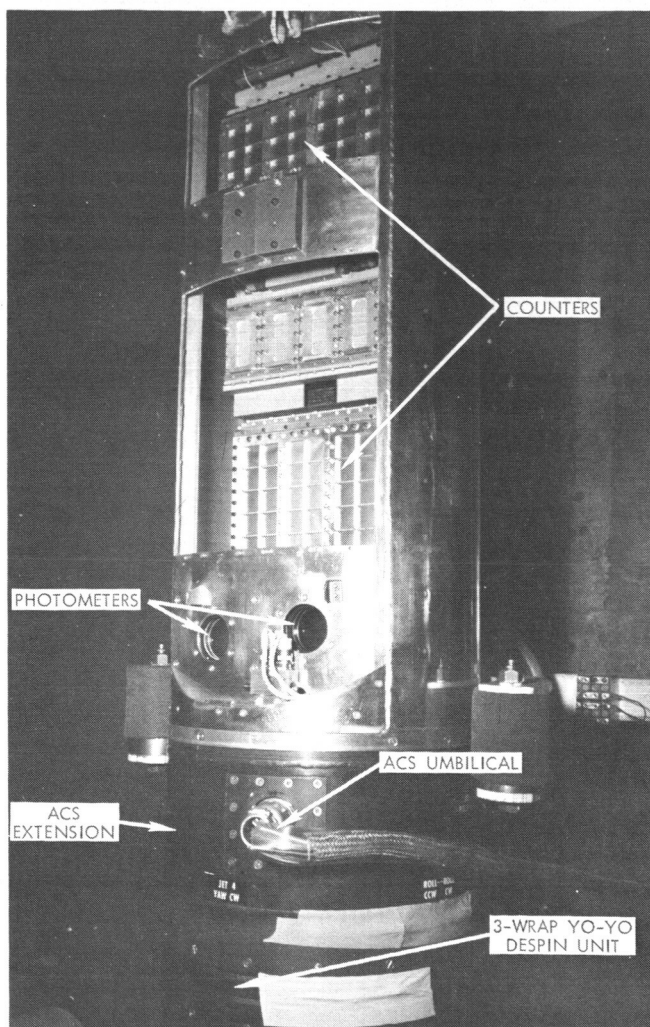
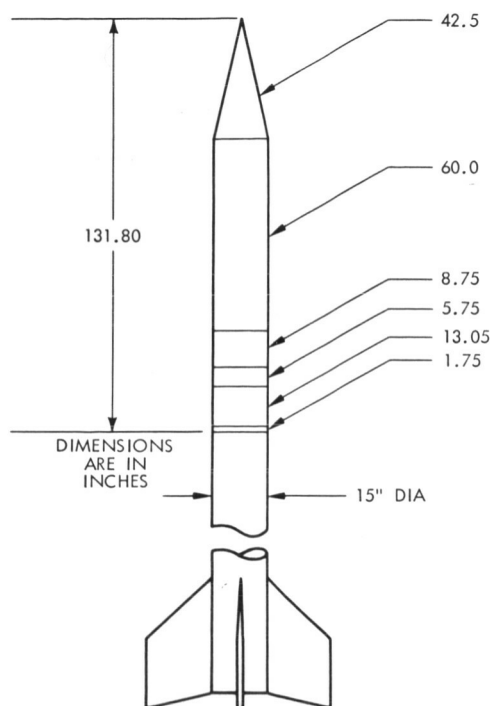


Figure 86. Flight 4.120 CG - Payload Configuration

Figure 87 gives payload dimensions and characteristics of this rocket and its flight.



FLIGHT 4.120 CG

FIRING DATE	1 OCT 1964
LAUNCH SITE	WSMR
PAYLOAD WT (LBS)	356.875
APOGEE (ST MI)	89.40
TIME TO APOGEE (SEC)	203.80
CENTER OF GRAVITY (CAL)	9.90
CENTER OF PRESSURE (CAL)	13.65
STATIC MARGIN (CAL)	3.65
RESTORING MOMENT (PER DEGREE)	-0.438
SUSTAINER BURNOUT TIME (SEC)	51.10 (T/M)
ROLL RATE AT BURNOUT (RPS)	2.10
NO. OF JOINTS	6.00

Figure 87. Flight 4.120 CG - Dimensions and Flight Characteristics

NASA Flight 4.123 CG

NASA 4.123 CG was successfully launched on 27 October from WSMR. A peak altitude of 119 statute miles was attained. Specific objectives for the rocket's payload included the collection of data on (1) flux levels over a range of 0.1 to 15 A (2) location of X-ray sources (3) measurement of the angular size of sources. This payload was similar to an earlier flight, 4.122 CG.

The payload shown in Figure 88 was housed in a 31 caliber fiberglass ogive nose cone which had been modified to incorporate three ejectable doors. The payload included four gieger counters, one photoelectric detector, two scintillation counters and two star sensors.

A recovery system was also included. The fins were cant to induce a roll rate of approximately 2.0 at sustainer burnout; actual was 1.8 rps. The rocket demonstrated good performance. Burnout velocity was 5280 ft/sec at 130,000 feet.

Telemetry instrumentation functioned until parachute system first severance at 250,000 feet (393 sec). The recovery system performed well, and the payload was quickly returned in good condition. The experiment was reported to have been successful.

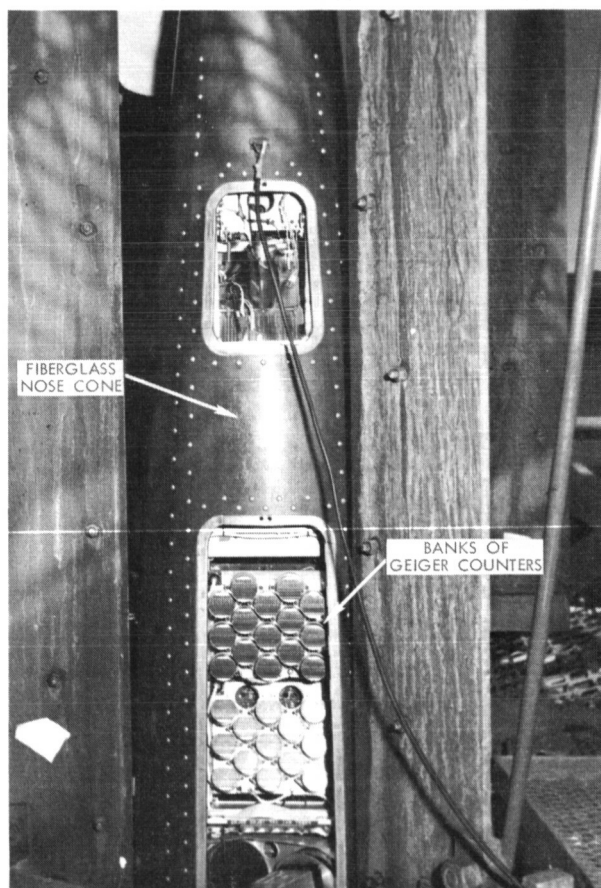


Figure 88. Flight 4.123 CG - Payload in Tower

Figure 89 gives payload dimensions and characteristics of this rocket and its flight.

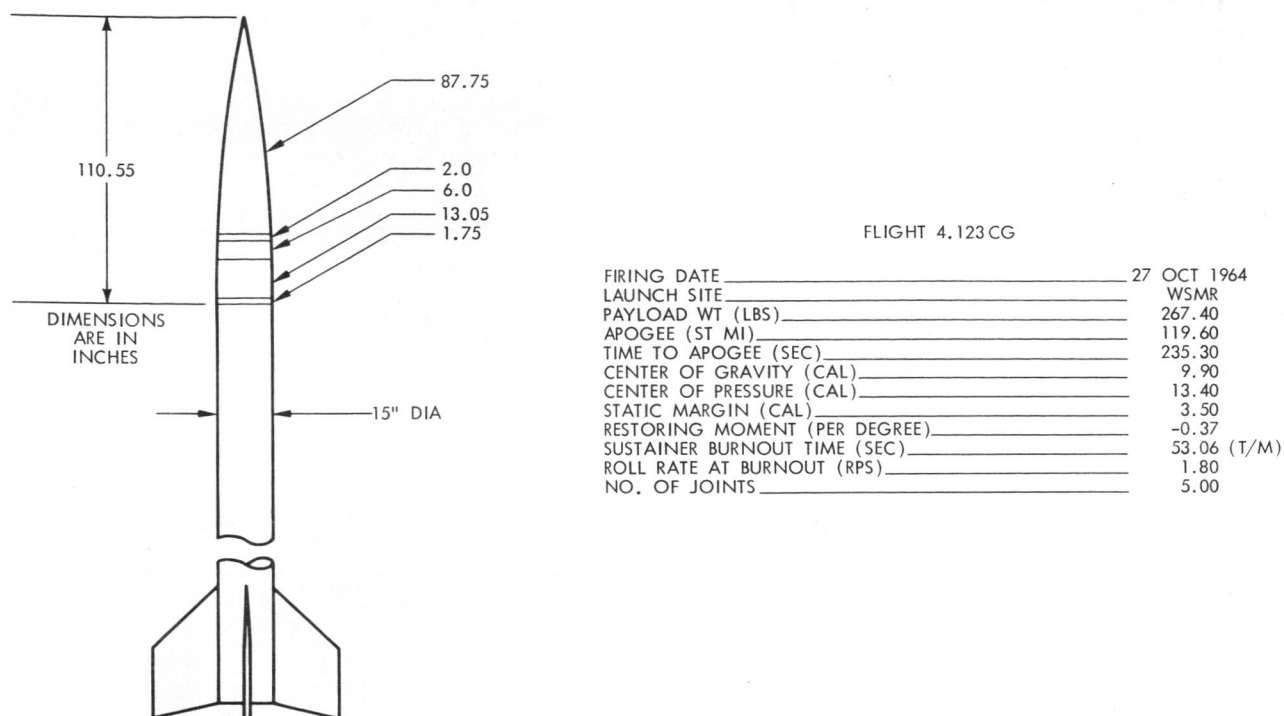


Figure 89. Flight 4.123 CG - Dimensions and Flight Characteristics

NASA Flight 4.116 GS

NASA 4.116 GS was immediately installed in the tower after 4.123 CG and successfully fired on 30 October. Figure 90 shows the rocket being hoisted into the White Sands tower. The payload utilized a Ball Brothers Research Corporation solar pointing control (SPC 300) instrument (Figure 91) for pointing the payload spectrometer at the sun. A solar spectrometer was used for taking solar spectral data in the 1-400 Å region. Additional objectives included adaption of the solar spectrometer for later flight on the OSO-C satellites, measurements of ionospheric electron density using a Faraday rotational unit, and measurements of the solar flux in the 1-10 Å region.

Booster and sustainer operation were normal with the vehicle reaching an apogee of 117.5 miles, 5 miles greater than predicted. All rocket instrumentation functioned well, and good telemetered data was received.

At 375,000 on the descent leg of the trajectory, the nose cone was retracted and locked into place. At approximately 300,000 feet the payload was severed from the rocket for payload recovery. Payload recovery was unsuccessful as the parachute apparently ripped off from the payload. Later analysis and flight data has confirmed the cause of the failure; this analysis is the subject of a paper presently in preparation (Reference 6) and is summarized in the following. The payload, after severance, re-entered in generally an aft end first mode; this is determined by the payload center of gravity and its long length. Because second severance is initiated by a 20,000 foot barometric switch, it is necessary that the switch be able to equalize to ambient pressure; if air is being "rammed" in the parachute extension as was indeed the case with the 4.116 GS payload, the barometric switch may sense a 20,000 foot pressure at some altitude higher than 20,000 feet. As the payload re-entered aft end first, air was "rammed in" the 3/8 inch diameter hole located on the cover plate. At 70,000 feet the barometric switches sensed more than 6.5 psi (20,000 feet equivalent), thereby actuating it and thus initiating the prima cord severance. The drogue chute



Figure 90. Rocket 4.116 GS being hoisted into WSMR Launch Tower

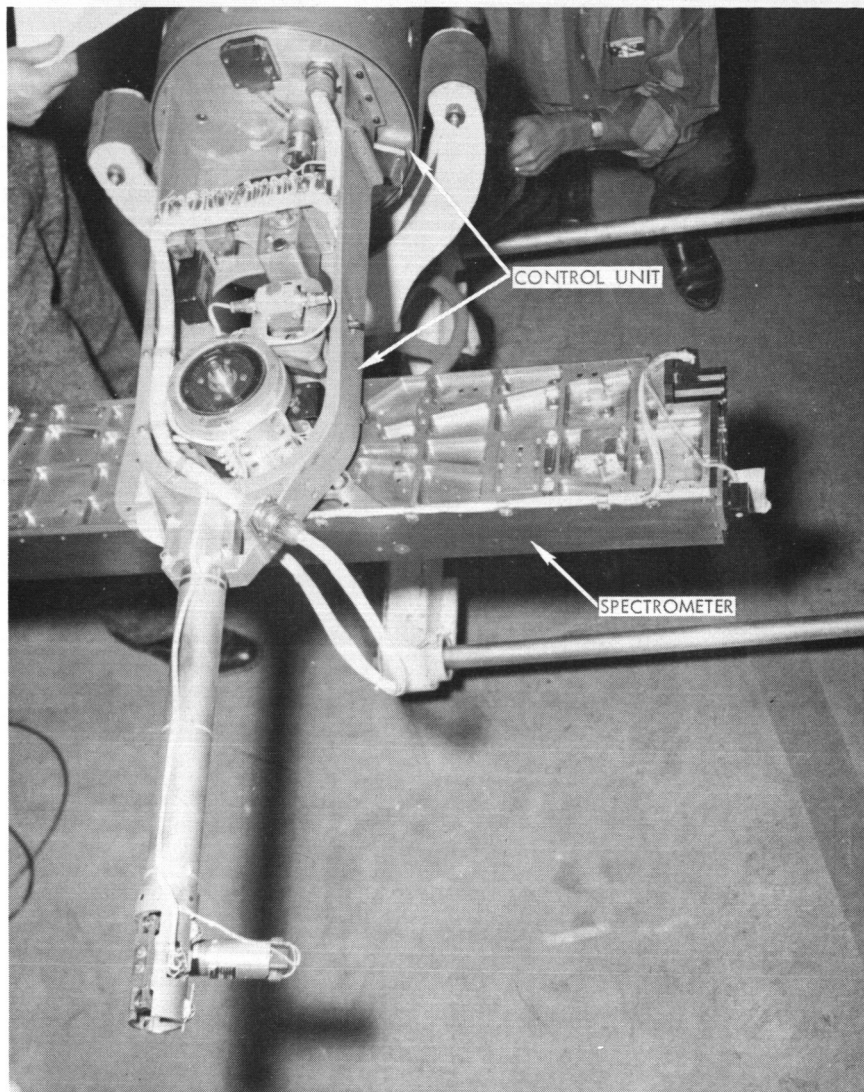
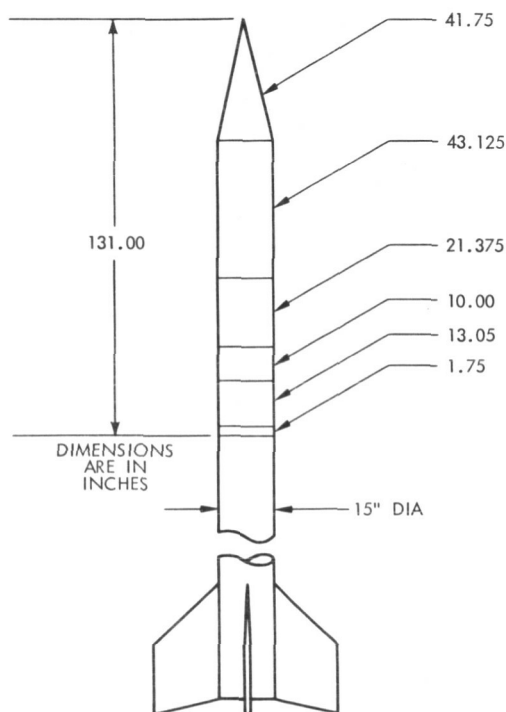


Figure 91. Flight 4.116 GS -
Solar Pointing Control During Checkout

was deployed at a re-entry velocity in excess of 600 feet per second but was, of course, unable to slow the payload down; the parachute was then deployed, and it was ripped from the recovery extension bulkhead. Figure 92a is a theoretical curve of the internal recovery extension pressure plotted against the ambient pressure.

Action taken after this failure, on subsequent recovery systems, included drilling holes on the side of the recovery extension thereby allowing the "ramming air" to vent out the side ports. This was done as a temporary remedial action until a more sophisticated and reliable system could be developed. "Ram pressure" effects on the Aerobee recovery system is a relatively new problem because of the heavier and longer payloads which are being flown and their tendency towards aft-end first re-entries.

The experiment was reported to have been approximately 75% successful. Figure 92 gives payload dimensions and flight characteristics of this rocket and its flight:



FLIGHT 4.116 GS

FIRING DATE	30 OCT 1964
LAUNCH SITE	WSMR
PAYLOAD WT (LBS)	287.40
APOGEE (ST MI)	119.00
TIME TO APOGEE (SEC)	234.40
CENTER OF GRAVITY (CAL)	10.60
CENTER OF PRESSURE (CAL)	13.25
STATIC MARGIN (CAL)	2.65
RESTORING MOMENT (PER DEGREE)	-0.294
SUSTAINER BURNOUT TIME (SEC)	54.45
ROLL RATE AT BURNOUT (RPS)	1.80
NO. OF JOINTS	5.00

Figure 92. Flight 4.116 GS - Dimensions and Flight Characteristics

NASA Flight 4.52 UG

NASA vehicle 4.52 UG was successfully launched from the White Sands Missile Range on 3 November at 0057 MST. The major experimental objectives were to take spectrographs in the ultraviolet of stars centered in the region of Orion.

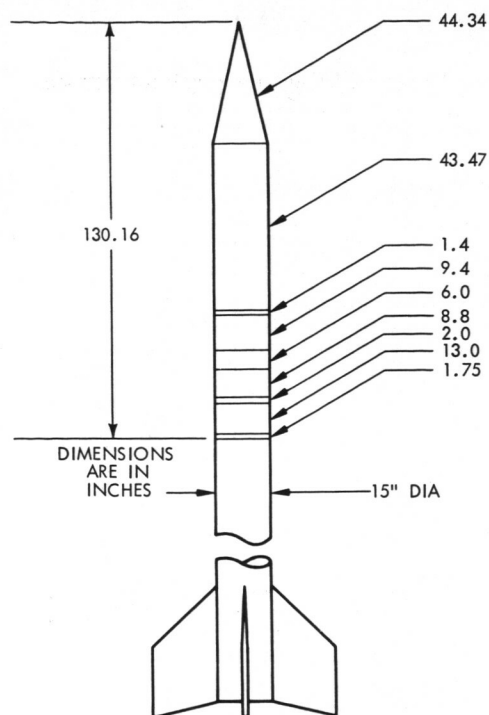
The standard Attitude Control System was equipped with a roll stabilized platform which was to minimize gyro drift thereby increasing spectrograph resolution.

The vehicle performed satisfactorily until T+48.9 seconds when range safety effected shut-off valve closure. The sustainer was apparently heading off range, due to an unexpected azimuth shift which may have resulted from a large wind shear or unconservative wind weighting. The approximately 3-second early shutdown was responsible for the thirty-eight mile loss in a predicted apogee of 116 statute miles.

The attitude control system (ACS) was actuated at burnout; 14 seconds were required for despin, but 30 seconds were required to successfully erect the vehicle to local vertical, a longer time than normally required. This longer time resulted from pitch and yaw jet impingement on the fins; impingement on a fin would induce a roll movement which would then have to be accounted for by the roll jets. The first maneuver was attempted but the ACS was unable to lock into position; fin impingement contributed to this failure.

However it was also determined that the pitch counter clockwise relay failed late in flight; this made it impossible to control the vehicle in the pitch axis. Excess fuel left in the tanks because of the early shutdown caused the roll and pitch valves to clog at times; fuel splattering on the ACS extension around the roll valves was evidenced when valve operations were checked following the flight.

The recovery system functioned as expected and the payload was returned in excellent condition. Figure 93 gives payload dimensions and characteristics of this rocket and its flight.



FLIGHT 4.52 UG	
FIRING DATE	3 NOV 1964
LAUNCH SITE	WSMR
PAYLOAD WT (LBS)	273.50
APOGEE (ST MI)	78.80
TIME TO APOGEE (SEC)	192.50
CENTER OF GRAVITY (CAL)	10.48
CENTER OF PRESSURE (CAL)	12.88
STATIC MARGIN (CAL)	2.40
RESTORING MOMENT (PER DEGREE)	-0.264
SUSTAINER BURNOUT TIME (SEC)	48.90 (T/M)
ROLL RATE AT BURNOUT (RPS)	1.95 (T/M)
NO. OF JOINTS	9.00

Figure 93. Flight 4.52 UG - Dimensions and Flight Characteristics

NASA Flights 4.109 GG and 4.110 GG

NASA 4.109 GG and 4.110 GG were flown 7 days apart on 7 and 14 November respectively. Experimental objectives were to measure the absolute intensity of specific stars in the ultra-violet region with 50 Å resolution. Each payload included a gas despin system to reduce vehicle roll rate after burnout to 0.05 rps. Good data was reportedly collected and both payloads were recovered with the standard land recovery system. Both payloads had pressurized ogive nose cones which were shortened from 87.8 inches to 84.3 inches.

Each experiment was comprised of 4 scanning photoelectric spectrophotometers; they were arranged in 2 pairs pointed 180° apart and were perpendicular to the spin axis of the rocket. Spectral scanning resulted from the slow spin of the rocket.

NASA Flight 4.109 GG—NASA vehicle 4.109 GG reached an apogee of 132 statute miles on 7 November. Figure 94 illustrates the lift off which occurred at 0348 MST. The vehicle performed satisfactorily and all instrumentation functioned as planned. Despin was initiated at T+69 seconds and 21.3 seconds were required to reduce from 2.0 rps to 0.05 rps. Net payload weight was 231.6 lbs, and velocity at burnout was 5,900 ft/sec.

Figure 95 gives payload dimensions and characteristics of this rocket and its flight.

NASA Flight 4.110 GG—NASA vehicle 4.110 GG was similarly successful and was launched at 0323:45 MST. A net payload weight of 236.5 lbs reached a peak altitude of 128 statute miles. Sustainer

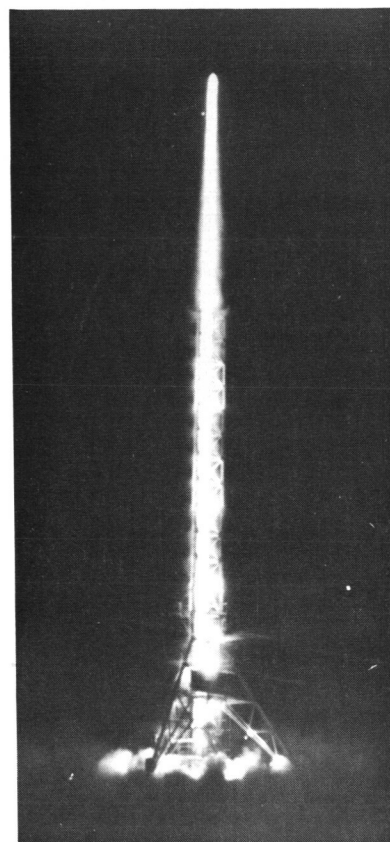
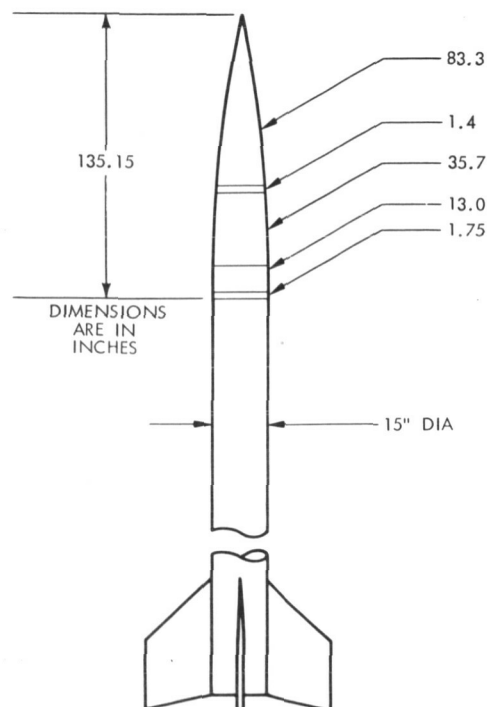


Figure 94. Flight 4.109 GG - Night Launch

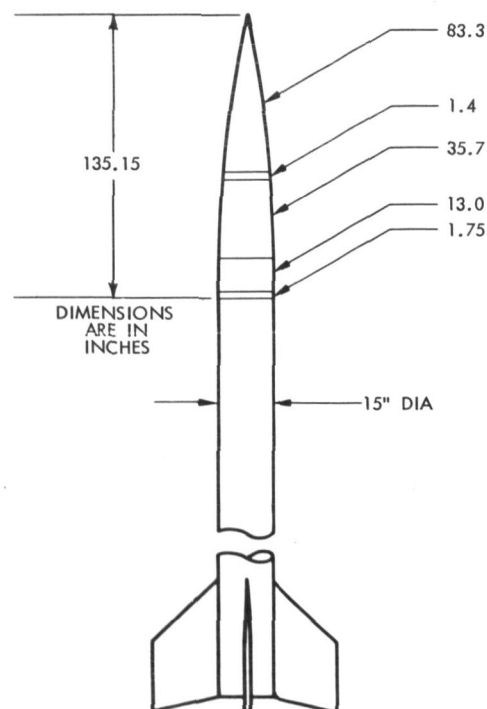
burnout occurred at 130,000 ft altitude at velocity of 5,600 ft/sec. Figure 96 gives payload dimensions and characteristics of this rocket and its flight.



FLIGHT 4.109GG

FIRING DATE	7 NOV 1964
LAUNCH SITE	WSMR
PAYLOAD WT (LBS)	231.60
APOGEE (ST MI)	130.70
TIME TO APOGEE (SEC)	243.90
CENTER OF GRAVITY (CAL)	11.40
CENTER OF PRESSURE (CAL)	14.10
STATIC MARGIN (CAL)	2.70
RESTORING MOMENT (PER DEGREE)	-0.280
SUSTAINER BURNOUT TIME (SEC)	53.20 (T/M)
ROLL RATE AT BURNOUT (RPS)	2.00 (T/M)
NO. OF JOINTS	5.00

Figure 95. Flight 4.109GG - Dimensions and Flight Characteristics



FLIGHT 4.110GG

FIRING DATE	14 NOV 1964
LAUNCH SITE	WSMR
PAYLOAD WT (LBS)	236.50
APOGEE (ST MI)	128.80
TIME TO APOGEE (SEC)	243.60
CENTER OF GRAVITY (CAL)	11.33
CENTER OF PRESSURE (CAL)	14.10
STATIC MARGIN (CAL)	2.77
RESTORING MOMENT (PER DEGREE)	-0.280
SUSTAINER BURNOUT TIME (SEC)	53.40 (T/M)
ROLL RATE AT BURNOUT (RPS)	2.10
NO. OF JOINTS	5.00

Figure 96. Flight 4.110GG - Dimensions and Flight Characteristics

NASA Flight 4.118 NA

NASA vehicle 4.118 NA was launched successfully from WSMR on 16 November. The flight appeared normal and the rocket performed near predicted. Peak altitude for the 314.8 lb net payload was 98.5 statute miles at T+215 sec. All rocket instrumentation performed as expected.

Primary objectives of this experiment were to evaluate the engineering performance of the Luster micrometeorite sampling experiment, as well as the collection of meteoritic debris during the peak of a Leonids meteor shower. A standard land recovery package was included in the rocket's configuration, and all joints (except the nose cone joint) were strengthened by the addition of sixteen screws.

Attitude during flight was monitored by a Whittaker gyro; a 3-axis vibration transducer was included to determine unexpected perturbations that could effect payload operation. Figures 97a and 97b show some of the payload angular pitch and yaw measurements taken. * Figure 97c illustrates the vehicle trajectory. *

At T+81.0 seconds the nose cone was unlatched and began to lift. The collecting arms extended and were fully open by T+90 seconds (See Figure 98). The experiment was apparently functioning as planned; due to a malfunction in the mechanical and hydraulic system, the nose cone was unable to fully retract. The collecting arms were exposed to the aerodynamic flow during payload re-entry, and whatever experimental data that had been collected was destroyed due to re-entry heating and atmospheric contamination. The payload was successfully recovered but was, of course, damaged. Figure 99 shows the special clean room which was necessary for the build up of this payload for flight. Figure 100 gives payload dimensions and characteristics of this rocket and its flight.

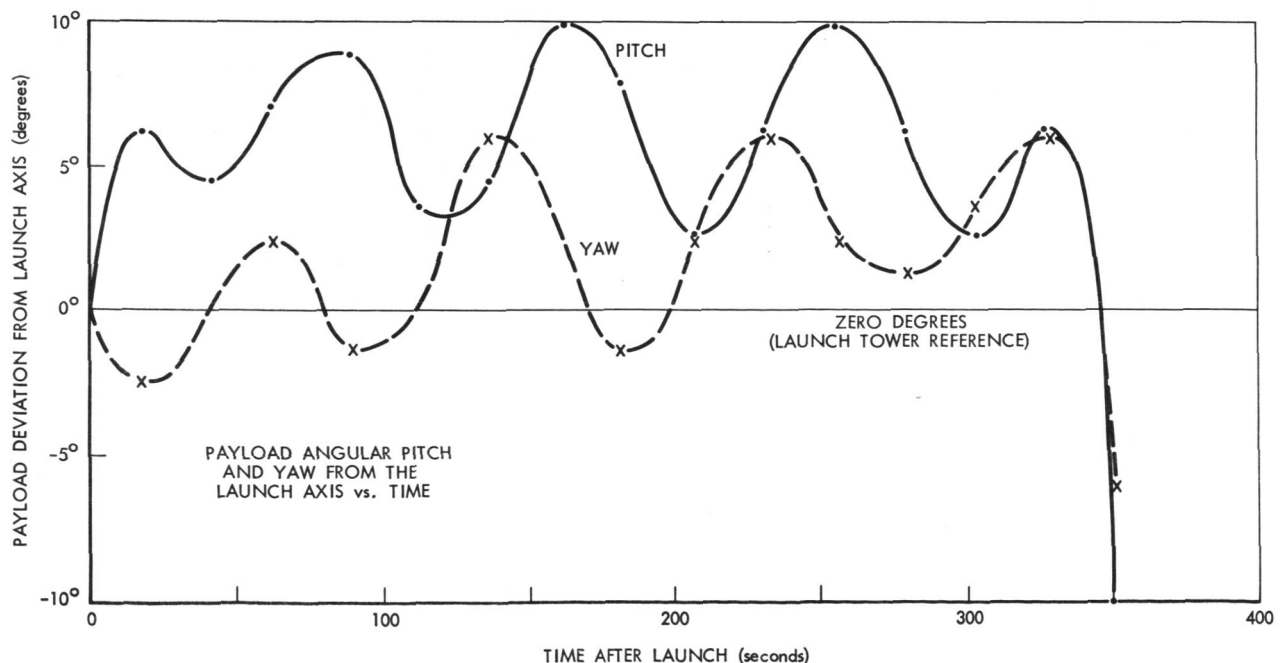


Figure 97a. Flight 4.118 NA - Payload Angular Pitch and Yaw from Launch Axis vs Time

* Preliminary Luster Flight Data Analysis; prepared by Luster Staff Ames Research Center (NASA) January 4, 1965

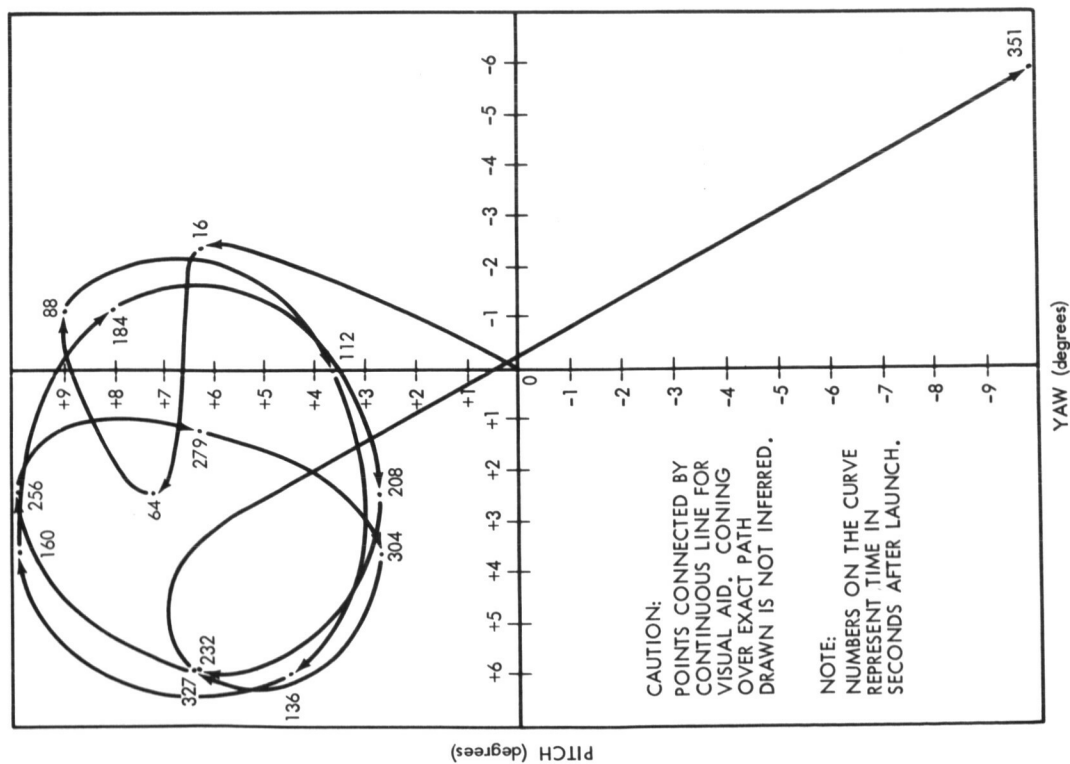


Figure 97b. Flight 4.118 NA - Payload Angular Deviation from Launch Axis vs Time

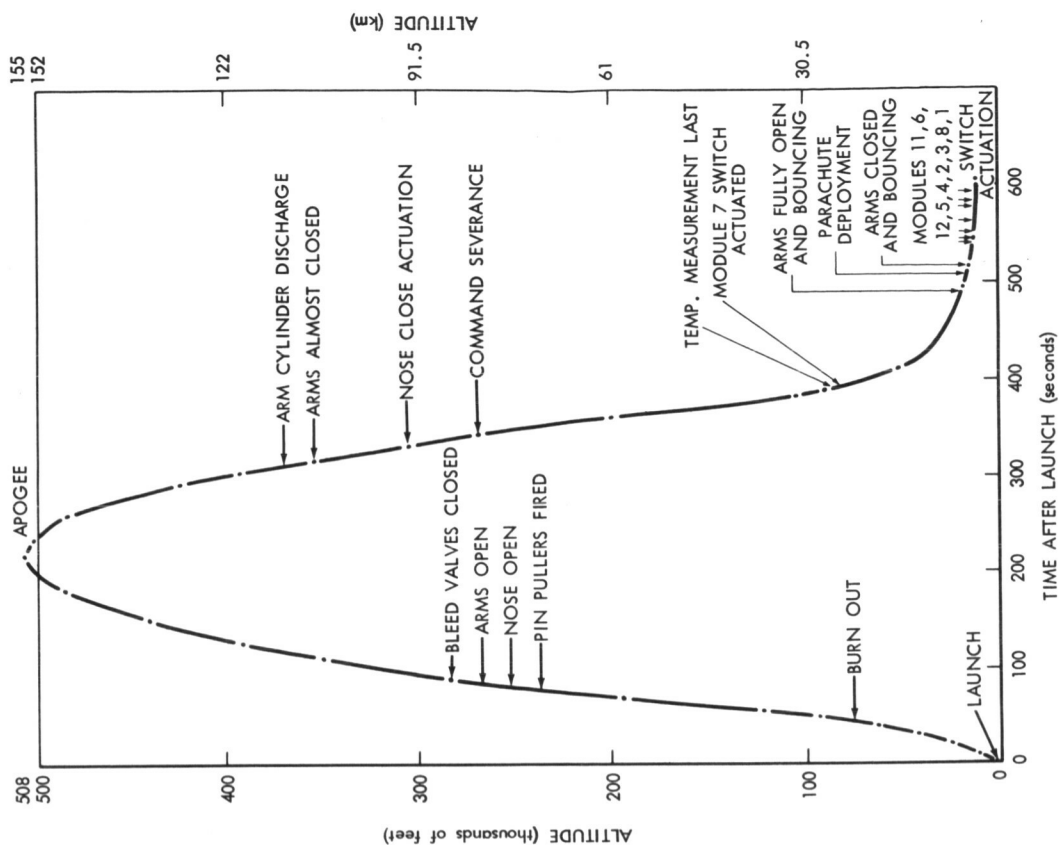


Figure 97c. Flight 4.118 NA - Payload Altitude vs Time after Launch



Figure 98. Flight 4.118 NA - Payload Deployed

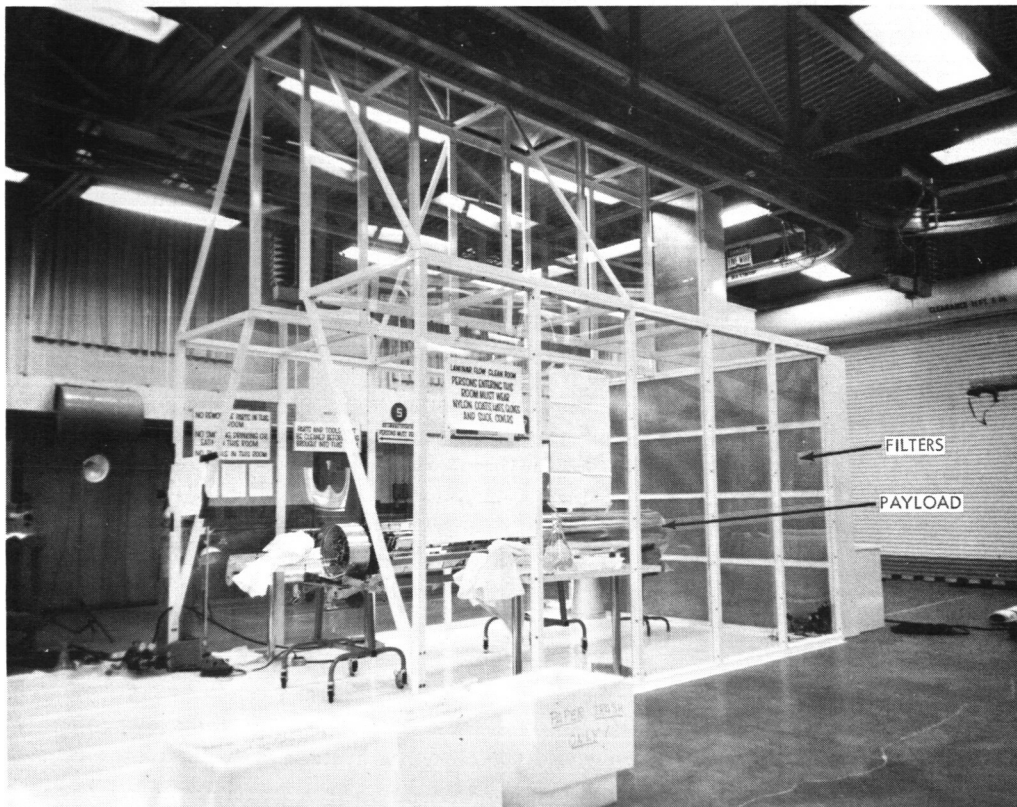
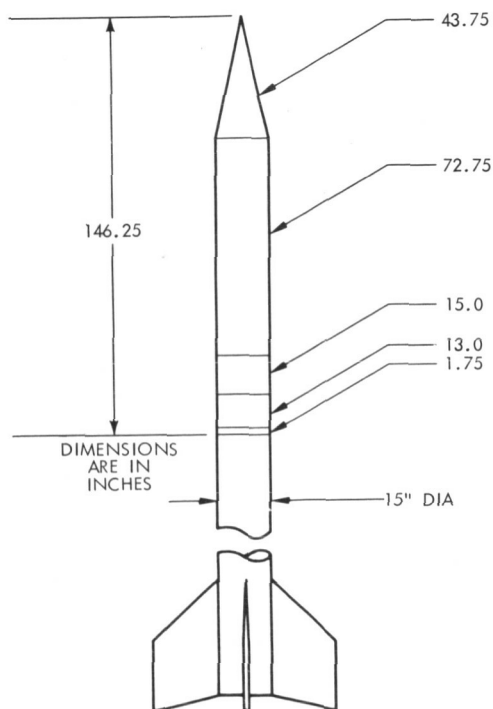


Figure 99. Clean Room Facility at WSMR (Used on Flight 4.118 NA)



FLIGHT 4.118 NA

FIRING DATE	1 DEC 1965
LAUNCH SITE	WSMR
PAYLOAD WT (LBS)	314.80
APOGEE (ST MI)	97.50
TIME TO APOGEE (SEC)	211.40
CENTER OF GRAVITY (CAL)	11.20
CENTER OF PRESSURE (CAL)	14.00
STATIC MARGIN (CAL)	2.90
RESTORING MOMENT (PER DEGREE)	-0.33
SUSTAINER BURNOUT TIME (SEC)	52.40
ROLL RATE AT BURNOUT (RPS)	2.00
NO. OF JOINTS	5.00

Figure 100. Flight 4.118 NA - Dimensions and Flight Characteristics

NASA Flight 4.45 GA

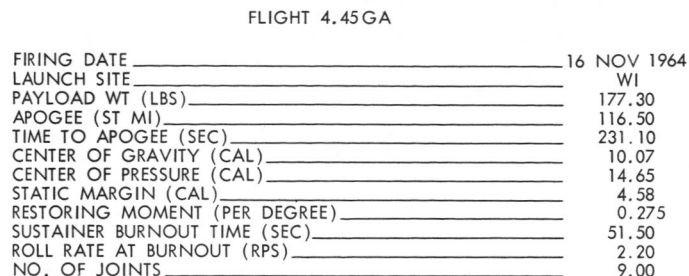
NASA vehicle 4.45 GA was launched successfully from Wallops Island on 16 November (See Figure 101). An electrostatic probe, an Omegaton, and a quadrapole mass spectrometer, all contained in a cylindrical "Thermosphere Probe," were used to measure the composition, density and temperature of neutral atmosphere in the 100-250 km altitude region. An additional secondary flight objective was the measurement of transverse forces acting on the vehicle from lift-off through launch tower exit. These measurements were made using load cells on the aft rail riding shoes.

The thermosphere probe was contained in a 6.5" diameter cone cylinder nose cone such as those used on Aerobee 300 and 300 A flights 6.01 GA through 6.10 GA. The nose cone, a clamshell, opened up during flight to eject the thermosphere probe. After the nose cone a transition section was mounted; this was mounted on a 9.4 in length extension housing instrumentation equipment. A gas despin mechanism was used to reduce roll rate after burnout.

The rocket and all rocket instrumentation performed well. Apogee was 117 statute miles. All experiments performed well sending and excellent data was reportedly received. Figure 102 gives payload dimensions and characteristics of this rocket and its flight.



Figure 101. Lift-off of NASA Flight 4.45 GA from Wallops Island Tower

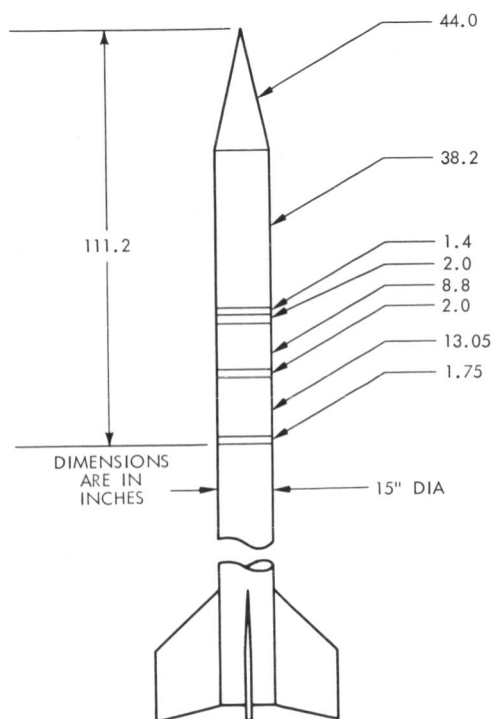


NASA Flight 4.83 GA

The rocket utilized two fast spectrographs for measurements in the ultraviolet of airglow. Each spectrograph was pointed out the side of the cylinder directing aft of the cone. The attitude control system, used for pointing the spectrographs at the nightglow horizon, performed as expected.

Despin was accomplished in 16.5 seconds, and sustainer burnout occurred at 52.4 seconds. The recovery system functioned, and the payload was recovered satisfactorily.

77



FLIGHT 4.83 GA

FIRING DATE	28 NOV 1964
LAUNCH SITE	WSMR
PAYLOAD WT (LBS)	237.50
APOGEE (ST MI)	114.30
TIME TO APOGEE (SEC)	231.60
CENTER OF GRAVITY (CAL)	9.91
CENTER OF PRESSURE (CAL)	12.25
STATIC MARGIN (CAL)	2.34
RESTORING MOMENT (PER DEGREE)	-0.252
SUSTAINER BURNOUT TIME (SEC)	52.20 (T/M)
ROLL RATE AT BURNOUT (RPS)	2.60 (T/M)
NO. OF JOINTS	8.00

Figure 104. Flight 4.83 GA - Dimensions and Flight Characteristics

NASA Flight 4.132 GA-GI

NASA Aerobee 4.132 GA-GI was launched from White Sands on 16 December. The rocket attained a peak altitude of 126.5 statute miles and performed as predicted.

In addition to the measuring the momentum energy of low velocity cosmic dust, the payload attempted to collect evidence of micrometeorites by impacts. The meteorite collectors were extended (as shown in Figure 105) at approximately T+60 seconds and remained extended until approximately T+457 seconds when a timer command was used to retract the collectors on the descent portion of the trajectory.

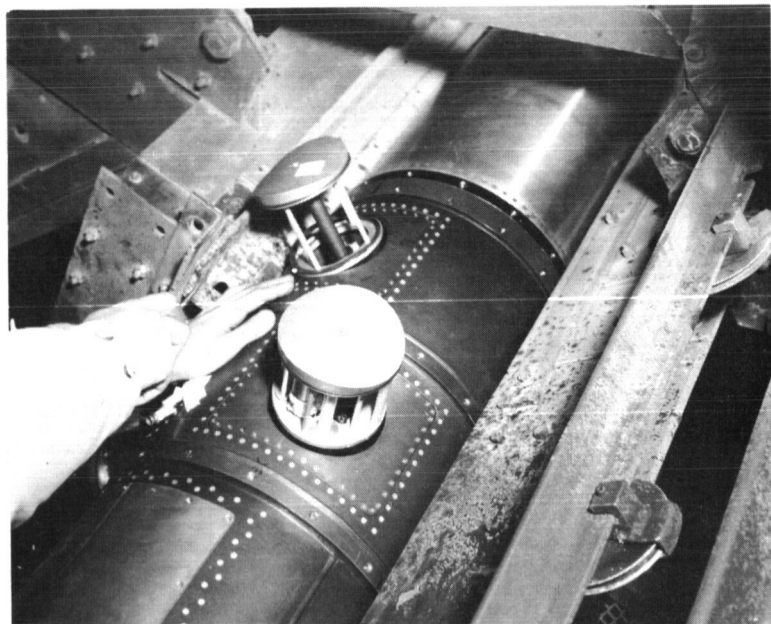


Figure 105. NASA Flight 4.132 GA - Meteorite Collectors, Extended Position

An ogive nose cone was used, and standard recovery package was successfully employed. Vent holes on the parachute extension had air filters to prevent outgassing contamination on the collecting arms.

No anomalies were experienced during flight, and all instrumentation performed as expected. The net payload weight was 243 lbs; apogee was 125 statute miles at 250 seconds.

The experiment was reported to have functioned successfully and

excellent data collected. Flight performance was monitored by a chamber pressure gauge, an accelerometer, and by longitudinal and roll magnetometers.

Figure 106 gives payload dimensions and characteristics of this rocket and its flight.

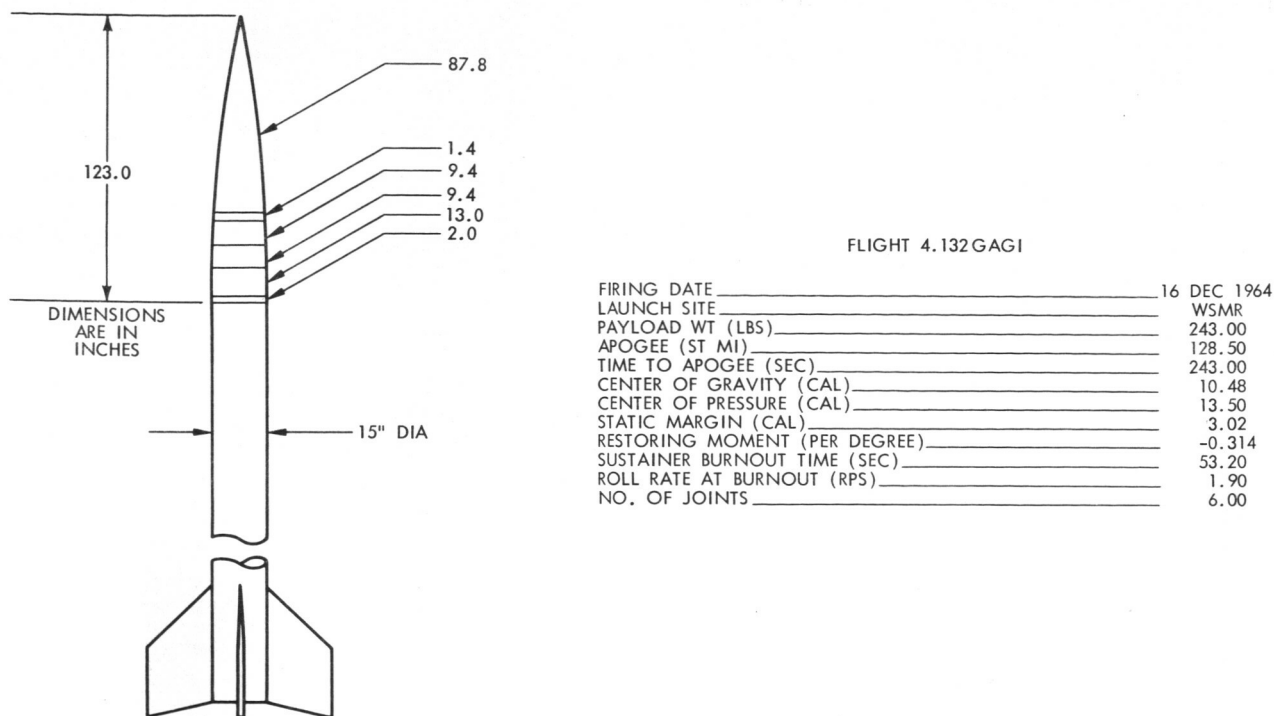


Figure 106. Flight 4.132 GA-GI - Dimensions and Flight Characteristics

NASA Flight 4.125 UA

The last Aerobee of 1964, NASA 4.125 UA, was fired in the late evening (2355 MST) on 16 December (17 December Zulu Time). The experiment was intended to study the distribution of Alpha radiation at the winter solstice when the anti-solar point was as high in the zenith as possible. In order to accomplish this objective the standard ACS was used for programming the rocket to scan the night sky. The payload used an Ebert-Fastie scanning ultraviolet spectrometer (with a telescope providing a narrow angle of view) and a JPL supplied narrow-angle of view photometer. The ACS program required the rocket to scan first East to West, then North to South.

A 3-wrap yo-yo despin unit was used to despin the rocket, thus conserving helium for use in the programmed ACS maneuvers.

The vehicle reached a peak altitude of 145.5 statute miles as predicted, and all aspects of the flight were close to predicted estimates. All instrumentation functioned as expected. The ogive nose cone was ejected during flight. The ACS performed satisfactorily until control was lost during the last yaw maneuver.

It was determined that this malfunction was due to the lack of sufficient helium pressure, thus inhibiting roll correction. This precluded proper vehicle maneuvering about the yaw axis. *From data received during flight there was reason to believe that the roll valve had not fully closed during maneuvers from 205 to 218 seconds, thus resulting in a large and costly pressure drop.

* Inter Office Memo D.J. Shrewsberry & H.W. Stintz to W.A. Russell, Jr. Engineering Section GSFC January 15, 1965

The 3-wrap yo-yo system despun the rocket from 2.17 rps to 0.3 in 7.36 seconds. Fin impingement from the gas plume was not considered a detrimental effect during this flight.

Significant scientific data was acquired. Figure 107 gives payload dimensions and flight characteristics for this rocket and its flight.

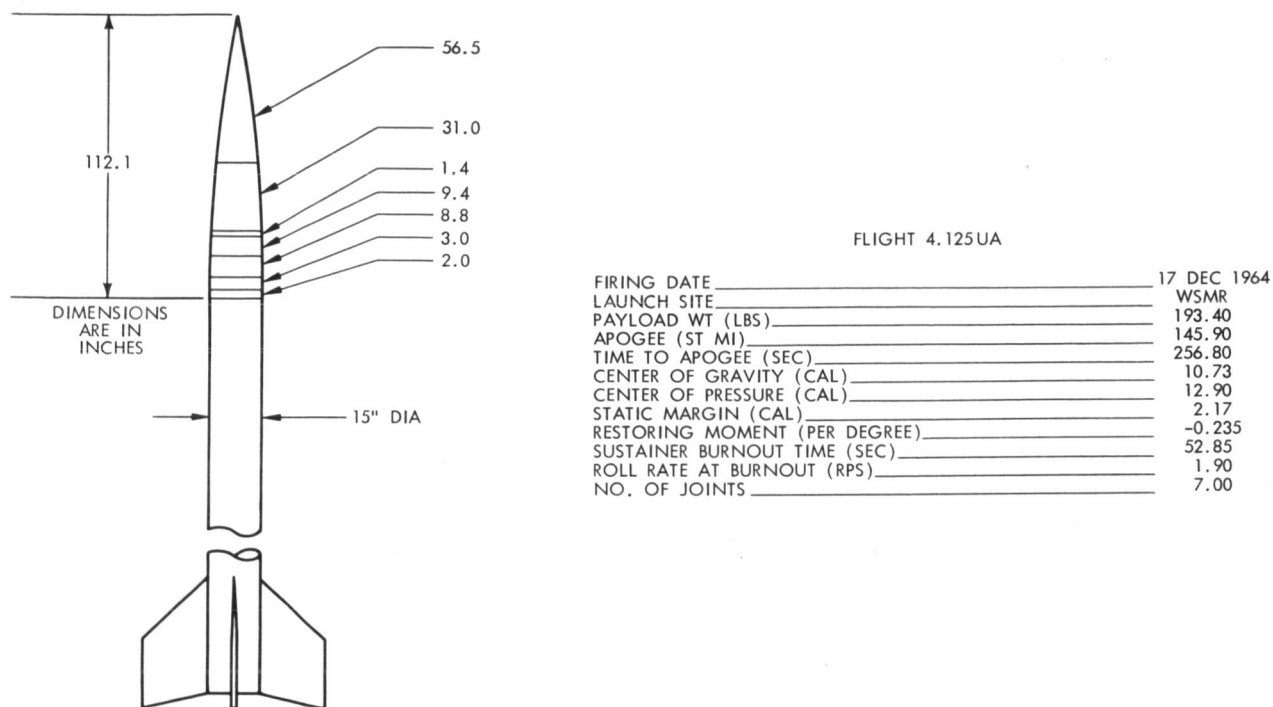


Figure 107. Flight 4.125UA - Dimensions and Flight Characteristics

CONCLUSIONS

This report summarizes all Aerobee sounding rocket launchings by the NASA Goddard Space Flight Center conducted during the calendar year. Further technical information concerning the Aerobee sounding rocket may be found in the bibliography.

ACKNOWLEDGMENTS

This work could not have been accomplished without the complete cooperation and support of Walter G. Moon, who helped to prepare this manuscript.

The authors also wish to express their appreciation for the use of U. S. Army official photographs (WSMR) and U. S. Air Force official photographs (F. C.) used in this report which were taken at those ranges.

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Appendix A

CROSS REFERENCE INDEX OF 1964 ROCKET LAUNCHINGS

All Sounding rocket launchings CY 1964 are listed in sequence by flight number. For each flight, the launch site and date, the rocket type and performance, the experiment scientist and sponsoring institute, and the rocket auxiliary systems are given.

FLIGHT NO.	LAUNCH SITE	LAUNCH DATE	ROCKET TYPE	ROCKET PERFORM	EXPERI-MENTER	TYPE EXPERIMENT	NOSE CONE
4.88 GT	WSMR	1-28-64	150	Satis	Russell GSFC	Attitude Control	Ogive
6.09 GA	WI	1-29-64	300 A	Satis	Brace GSFC	Therm Probe	Ogive
4.124 UA	FC	2-27-64	150	Partial Success	Fastie JHU	Aurora	Cone Cyl
4.15 GG	WSMR	4-2-64	150	Satis	Boggess GSFC	Stellar Spectra	Cone Cyl
4.81 GG	WSMR	4-10-64	150	Unsatis	Boggess GSFC	Stellar Spectra	Cone Cyl
4.86 NA	WSMR	4-14-64	150	Unsatis	Barth JPL	Airglow	Modified Cone Cyl
4.113 GAGI	WSMR	4-21-64	150	Unsatis	Berg-Aikin GSFC	Astrochemistry Ionospheres	Ogive
4.67 NP	WSMR	6-10-64	150	Satis	Kinard LRC	Meteorite Sam-ple Paraglider	Modified Ogive
4.107 GE	FC	7-23-64	150	Satis	Fichtel GSFC	Heavy Cosmic Rays	Ogive
4.108 GE	FC	7-25-64	150	Satis	Fichtel GSFC	Heavy Cosmic Rays	Cone Cyl
6.10 GA	FC	7-28-64	300	Satis	Brace GSFC	Thermosphere Probe	Cone Cyl
4.82 GG	WSMR	8-11-64	150	Satis	Boggess GSFC	Stellar Spectra	Modified Cone Cyl
4.126 GG	WSMR	8-22-64	150	Partial Success	Boggess GSFC	Stellar Spectra	Cone Cyl
4.122 CG	WSMR	8-29-64	150	Satis	Gursky AS&E	Stellar Studies	Mod Fiber-glass Ogive

ATTIT CONTROL SYS	SPC	RECOVERY SYSTEM	DESPIN SYSTEM	REMARKS	PAGE NO.
Yes	None	Yes	None	Good ACS & recovery.	
None	None	None	None		
None	None	None	None	Failed to reach expected peak alt due to pitch/roll coupling.	
Yes	None	Yes	None	ACS failed. Good recovery.	
Yes	None	Yes	None	Pitch roll coupled. Attit control sys - no oppor to funct. Good recovery.	
Yes	None	Yes	None	Pitch roll coupled.	
None	None	Yes	None	Propulsion sys failure. Recov sys - no oppor to function.	
None	None	Paraglider	Gas	Paraglider recov - partial suc- cess. Gas sys function - good.	
None	None	Yes	None	Good recov sys operation.	
None	None	Yes	None	Good recov sys operation.	
None	None	None	None		
Yes	None	Yes	None	ACS failure due to leak in the despin valve. Good recovery.	
Yes	None	Yes	None	Chamber inner liner burn through. Good recov. Satis ACS.	
None	None	Yes	None	Good recovery.	

FLIGHT NO.	LAUNCH SITE	LAUNCH DATE	ROCKET TYPE	ROCKET PERFORM	EXPERI-MENTER	TYPE EXPERIMENT	NOSE CONE
4.55 UG	WI	9-2-64	150A	Satis	Bless U. Wisc.	Stellar Studies	14.2 in. Cone Cyl
4.115 NA	WI	9-18-64	150A	Satis	Barth JPL	Dayglow	Modified Cone Cyl
4.13 GPGT	WI	9-27-64	150A	Satis	Busse GSFC	Rocket Test	Cone Cyl
4.120 CG	WSMR	10-1-64	150	Satis	Fisher LMSC	Stellar X-Ray	Cone Cyl
4.123 CG	WSMR	10-27-64	150	Satis	Gursky AS&E	Stellar Studies	Fiberglass Ogive
4.116 GS	WSMR	10-30-64	150	Satis	Muney GSFC	Solar Studies	Modified Cone Cyl
4.52 UG	WSMR	11-3-64	150	Partial Success	Morton PUO	Stellar Spectra	Cone Cyl
4.109 GG	WSMR	11-7-64	150	Satis	Stecher GSFC	Stellar Spectra	Ogive
4.110 GG	WSMR	11-14-64	150	Satis	Stecher GSFC	Stellar Spectra	Ogive
4.45 GA	WI	11-16-64	150A	Satis	Brace GSFC	Therm Probe	Sim Sparrow Cone Cyl
4.118 NA	WSMR	11-16-64	150	Satis	Pochari Ames	Micrometeorite	Cone Cyl
4.83 GA	WSMR	12-1-64	150	Satis	Hennes GSFC	Middle UV Airglow	Cone Cyl
4.132 GAGI	WSMR	12-16-64	150	Satis	Berg GSFC	Micrometeorite	Ogive
4.125 UA	WSMR	12-17-64	150	Satis	Fastie JHU	Airglow	Ogive

ATTIT CONTROL SYS	SPC	RECOVERY SYSTEM	DESPIN SYSTEM	REMARKS	PAGE NO.
None	None	None	Gas	Good Gas despin operation.	
Yes	None	None	None	Good ACS.	
Yes	None	Yes	YoYo	Recov failure. ACS failed. YoYo failed.	
Yes	None	Yes	YoYo	Good ACS.	
None	None	Yes	None	Telem rec'd to 393sec @ sep- aration. Good recovery.	
None	SPC-300	Yes	None	Good SPC operation. Recovery failure.	
Yes	None	Yes	None	Cut down by range safety @ 48.85 sec. ACS partial. Recov success.	
None	None	Yes	Gas	Telem rec'd for 405 sec. Good recovery & despin.	
None	None	Yes	Gas	Good recov & despin operation.	
None	None	Yes	Gas	Good recov & gas despin.	
None	None	Yes	None	Longest cone cyl cone flown. Manfunct of the hydraulic sys in payload section. Good recovery.	
Yes	None	Yes	None	Good ACS & recovery.	
None	None	Yes	None	Good recovery.	
Yes	None	None	YoYo	ACS unable to control in last yaw maneuver. 1st time ACS success flown twice. Partial ACS system. Good despin.	

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Appendix B

PERFORMANCE CHARACTERISTICS CHARTS

Performance characteristics charts for the Aerobee 150 and 150 A are contained on pages 90 through 92. They include the following:

1. Peak altitude vs net payload for ogival nose cones.
2. Peak altitude vs net payload for conical nose cones.
3. Altitude and velocity vs time for various payloads.
4. Summit time vs net payload for ogival nose cones.
5. Acceleration vs time for typical flights.

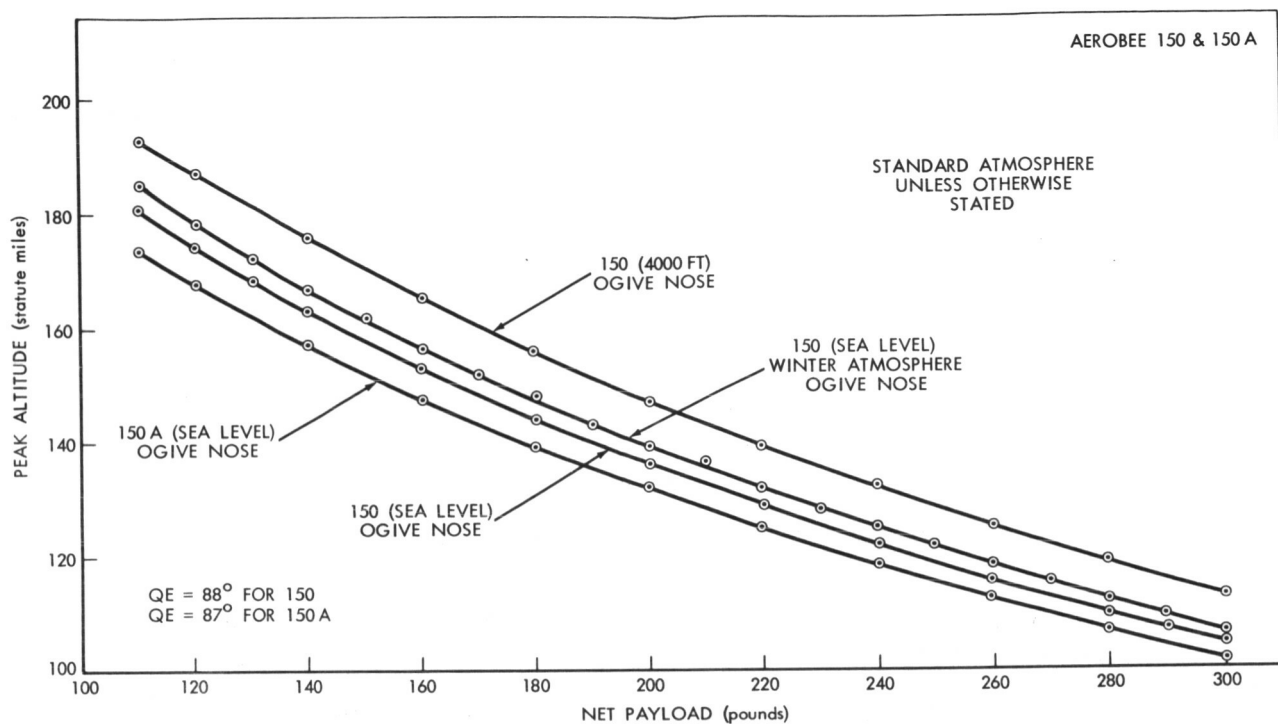


Figure B1. Peak Altitude vs Net Payload for Ogival Nose Cones

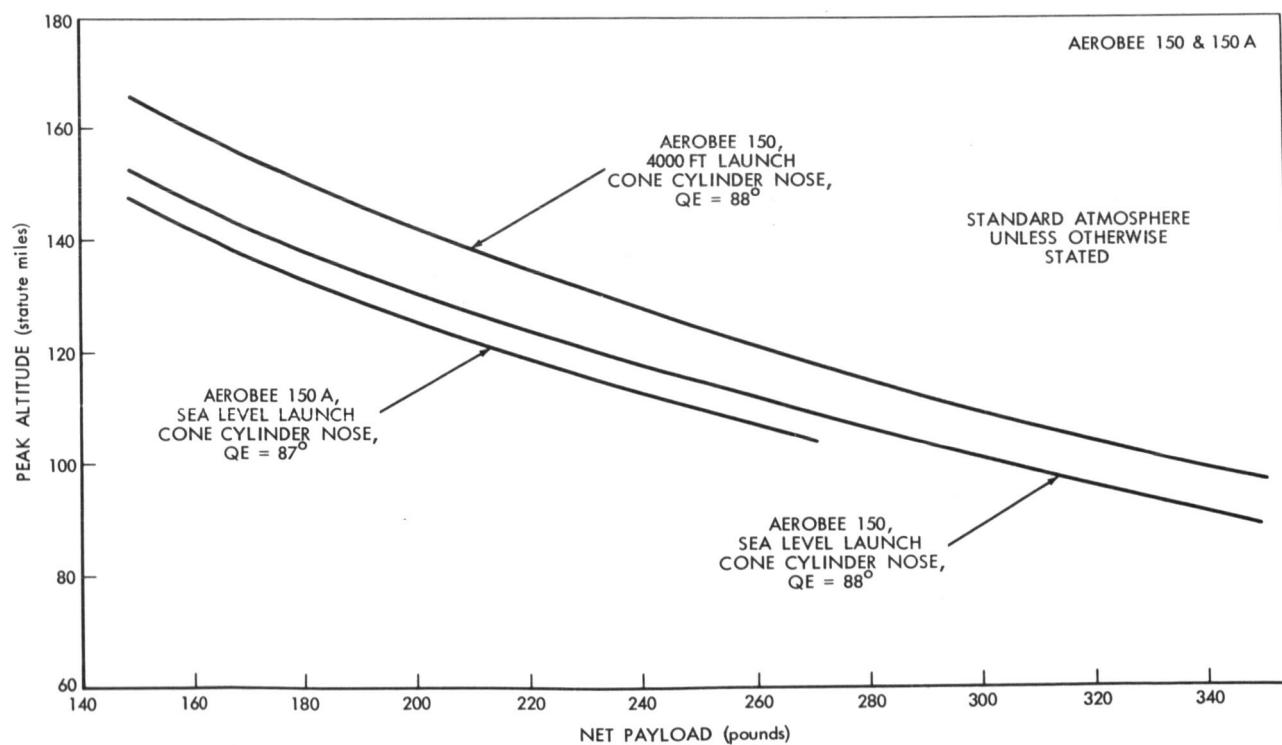


Figure B2. Peak Altitude vs Net Payload for Cone-Cylinder Nose Cones

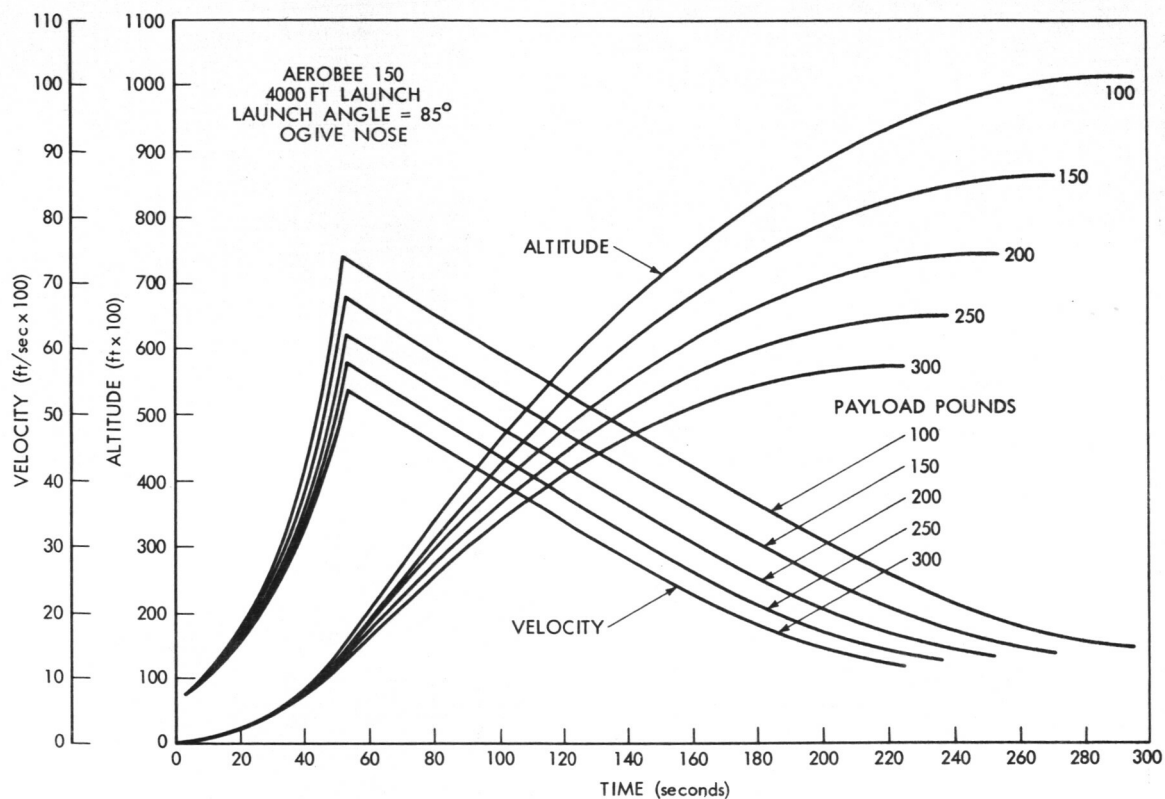


Figure B3. Aerobee 150 Velocity and Altitude vs Time for Various Payloads

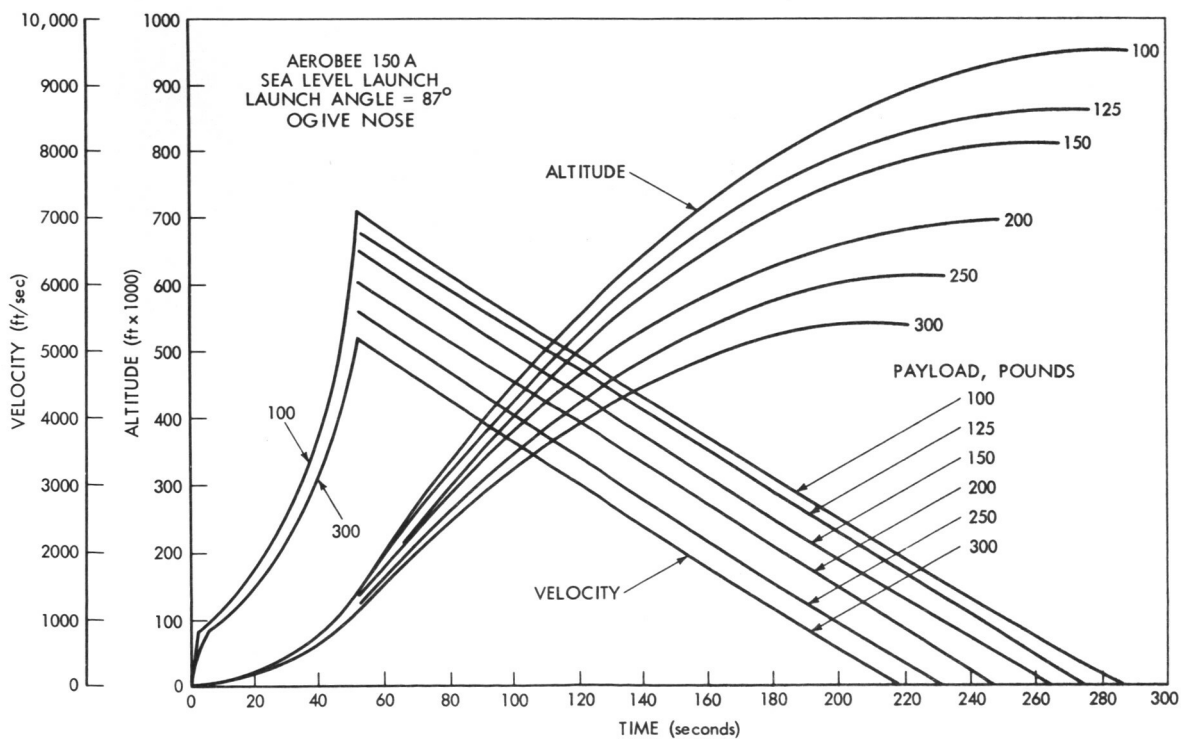


Figure B4. Aerobee 150 A Velocity and Altitude vs Time for Various Payloads

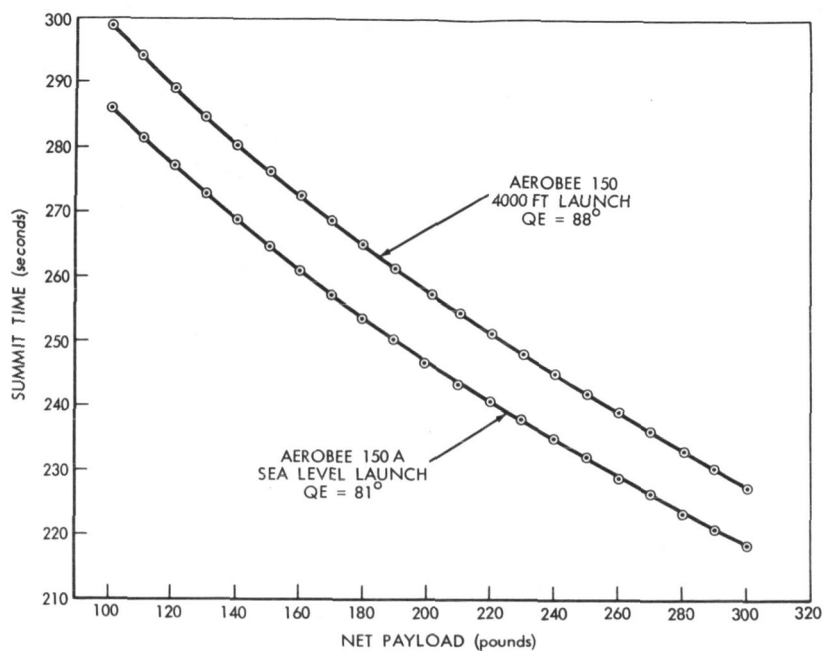


Figure B5. Summit Time vs Net Payload for Aerobee 150 and 150 A Sounding Rockets with Ogival Nose Cones

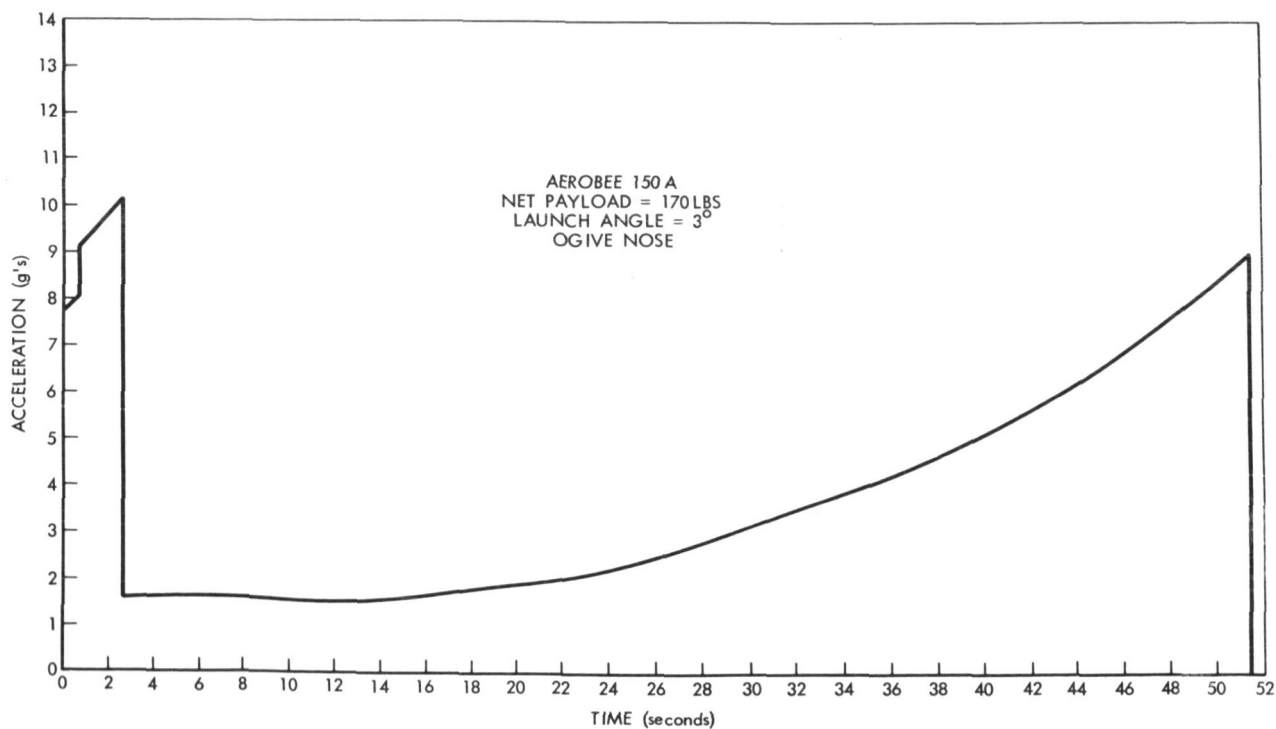


Figure B6. Acceleration vs Time for Aerobee 150 A (Typical)

Appendix C

INDEX OF REDUCED PERFORMANCE DATA 1964 FLIGHTS

An Index of Representative Data reduced for 1964 Aerobee flights is presented on page 95. For each flight represented, the figure number is provided which refers to its location within the report.

DATA	FT					
	4.15 GG	4.81 GG	4.86 NA	4.126 GG	4.55 UG	4.115 NA
Roll Rate vs Time	Figure 22	Figure 27	Figure 30			
Pc vs Time	Figure 23	Figure 28	Figure 32	Figure 61	Figure 68 a	Figure 74
Acceleration vs Time	Figure 26	Figure 28	Figure 31	Figure 63	Figure 68 b	Figure 75
Yaw Frequency vs Time	Figure 22	Figure 27	Figure 29		Figure 69	
Pitch Frequency vs Time	Figure 22	Figure 27		Figure 64		
Pox vs Time						Figure 74
Pfl vs Time						Figure 74
Wind Velocity & Azimuth vs Time		Figure 26	Figure 33			
Altitude vs Time				Figure 71		
Temperature Data						
Booster Pressure vs Time						
Booster Acceleration vs Time						
Velocity vs Time						
Remarks	Typical WSMR Cone Cyl	Aero Perform Failure	Aero Perform Failure	Thrust Chamber Burn Through	WI Typical Low	WI Typical ACS Cone Cyl

C
 PERFORMANCE DATA
 LIGHTS

LIGHT NUMBER

4.113 GAGI	4.67 NP	4.107 GE	4.124 UA	4.88 GT	6.09 GA	4.13 GP GT
Figure 39	Figure 42		Figure 18	Figure 7 c		
Figure 38		Figure 49	Figure 17	Figure	Figure 12	Figure 82
Figure 37		Figure 48	Figure 17	Figure 7 b	Figure 13	Figure 81
						Figure 81
Figure 37						Figure 81
				Figure 7 d		Figure 82
				Figure 7 e		Figure 82
	Figure 43		Figure 20	Figure 7 a		Figure 83
						Figure 79
					Figure 9	Figure 84
					Figure 11	
	Figure 44					Figure 83
Hard Start	Typical Heavy	Typical Churchill	Pitch Roll Coupling	Typical Ogive WSMR	Insul Booster	Perform Rocket

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Appendix D

SUMMARY OF 1964 FLIGHT PERFORMANCE STATISTICS

Flight performance statistics such as net payload weight, apogee, Cg, Cp, burnout, roll rate, etc. are provided on pages 99 and 101. Each Aerobee flight launched during 1964 is included.

APPEND
SUMMARY OF 1964 FLIGHT PR
NASA AEROBEE 150 A

FLIGHT NO.	LAUNCH DATE	LAUNCH SITE	NET PAYLOAD WT (LBS)	TIME TO APOGEE (SEC)	APOGEE (ST MI)	SUSTAINER BURNOUT TIME (SEC)
4. 88 GT	1-28-64	WSMR	291.0	252.6	123.7	53.05
4. 124 UA	2-27-64	FC	137.5	218.0	100.0	53.0
4. 15 GG	4-2-64	WSMR	258.0	235.0	118.6	52.4
4. 81 GG	4-9-64	WSMR	271.5	141.8	45.5	52.6
4. 86 NA	4-14-64	WSMR	277.23	77.4	193.0	53.04
4. 113 GA-GI	4-21-64	WSMR	239.0	29.2	6.6	27.5
4. 67 NP	6-10-64	WSMR	353.9	211.1	96.4	52.10
4. 107 GE	7-23-64	FC	185.4	267.0	144.5	53.0
4. 108 GE	7-25-64	FC	179.5	251.0	133.7	51.7
4. 82 GA	8-11-64	WSMR	286.0	221.3	107.1	52.2
4. 126 GG	8-22-64	WSMR	265.6	190.0	76.6	48.7
4. 122 CG	8-29-64	WSMR	264.1	225.7	111.2	52.0
4. 55 UG	9-2-64	WI	219.8	215.1	97.1	51.7
4. 115 NA	9-18-64	WI	240.0	222.1	104.4	52.2
4. 13 GP-GT	9-27-64	WI	341.8	190.0	74.5	50.8
4. 120 CG	10-1-64	WSMR	356.9	203.8	89.4	51.1
4. 123 CG	10-27-64	WSMR	267.4	235.3	119.6	53.06
4. 116 GS	10-30-64	WSMR	287.4	234.4	119.0	54.45
4. 52 UG	11-3-64	WSMR	273.5	192.5	78.8	48.9
4. 109 GG	11-7-64	WSMR	231.6	243.9	130.7	53.2
4. 110 GG	11-14-64	WSMR	236.5	243.6	128.8	53.4
4. 45 GA	11-16-64	WI	177.3	231.1	116.5	51.5
4. 118 NA	11-16-64	WSMR	314.8	211.4	97.5	52.4
4. 83 GA	11-28-64	WSMR	237.5	231.6	114.3	52.2
4. 132 GA-GI	12-16-64	WSMR	243.0	243.0	128.5	53.2
4. 125 UA	12-17-64	WSMR	193.4	256.8	145.9	52.9

IX D
PERFORMANCE STATISTICS
ND 150 A FLIGHTS

STATIC MARGIN (CALIBERS)	CENTER OF GRAVITY (CALIBERS)	CENTER OF PRESSURE (CALIBERS)	RESTORING MOMENT (PER DEGREE)	ROLL RATE @ BURNOUT	TOTAL NO. OF JOINTS
3.15	10.8	13.95	0.315	1.45	8
2.0	10.0	12.2	0.215	0.5	4
2.2	11.0	13.2	0.23	1.55	11
2.42	10.98	13.40	0.265	0.53	11
2.2	11.34	13.54	0.244	Unknown	11
3.23	10.43	13.6	0.103	Unknown	7
3.6	11.4	15.0	0.396	2.5	3
2.43	10.82	13.25	0.245	1.8	4
2.55	10.70	13.25	0.255	2.2	4
2.51	9.84	12.35	0.284	2.25	8
2.72	9.81	12.5	0.278	1.9	8
3.2	10.0	13.2	0.336	1.1	5
2.98	9.34	12.32	0.410	2.5	4
2.96	9.67	12.72	0.407	—	7
3.15	11.06	14.21	0.53	—	11
3.65	9.9	13.65	0.438	2.1	6
3.5	9.9	13.4	0.37	1.8	5
2.65	10.6	13.25	0.294	1.8	6
2.40	10.48	12.88	0.264	1.95	9
2.7	11.4	14.1	0.280	2.0	5
2.77	11.33	14.1	0.280	2.1	5
4.58	10.07	14.65	0.275	2.2	9
2.9	11.2	14.0	0.33	2.0	5
2.34	9.91	12.25	0.252	2.6	8
3.02	10.48	13.5	0.314	1.9	6
2.17	10.73	12.9	0.235	1.9	7

APPENI
SUMMARY OF 1964 FLIGHT PERFO
NASA AEROBEE 300 A

NASA	Launch Date	Launch Site	Net Payload Wt 2 nd Stg (lbs)	Apogee (St Mi)	Time To Apogee (Sec)	Center of Gravity Sustainer @ Burnout (Calibers)	Static Margin Sustainer @ Burnout (Calibers)	Center of Pressure Sustainer @ Burnout (Calibers)	Restoring Moment Sustainer @ Burnout (Per Degree)
6.09 GA	1-29-64	WI	273.1	192.3	300.2	11.25	4.37	15.62	0.594
6.10 GA	7-28-64	FC	253.4	200.0	305.0	10.90	3.85	14.75	0.400

IX D
 RMANCE STATISTICS (Continued)
 ND 300 A FLIGHTS

Center of Gravity 3rd Stg @ Burnout (Calibers)	Center of Pressure 3rd Stg @ Burnout (Calibers)	Static Margin 3rd Stg @ Ignition (Calibers)	Restoring Moment 3rd Stg @ Ignition (Per Degree)	Sustainer @ Burnout (Sec)	3rd Stg @ Burnout (Sec)	Roll Rate @ Burnout Sustainer (lbs)	Total Number Joints	Net Payload Wt 3rd Stg (lbs)
7.8	11.16	3.36	0.121	50.8	53.8	2.7	4	84.75
8.38	11.4	3.02	0.110	54.0	Unknown	2.0	8	96.98

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Appendix E

ABBREVIATIONS AND DEFINITIONS

ACS	Attitude control system
AFCRL	U. S. A. F. Cambridge Research Laboratory, Bedford, Mass.
AGC	Aerojet-General Corporation, Azusa, Calif.
Ames	Ames Research Center, NASA, Moffet Field, Calif.
ANCSR	Australian National Committee for Space Research
AS&E	American Science & Engineering, Inc., Cambridge, Mass.
BBRC	Ball Bros. Research Corporation, Boulder, Colo.
BPC	Biaxial pointing control
BRL	Ballistics Research Laboratory, Aberdeen Proving Ground, Md.
CNET	Centre National d'Etudes Telecommunications, Paris, France
DRTE	Defense Research Telecommunications Establishment, Canada
EOGO	Eccentric Orbiting Geophysical Observatory
FACS	Fine attitude control system
FC	Fort Churchill Launch Facility, Ft. Churchill, Manitoba, Canada
FPS-16	A C-band, high precision monopulse missile tracking radar with a 16-foot parabolic reflector and a 1000 mile beacon tracking range (150 miles passive), providing real-time present-position analog data for range safety.
GSFC	Goddard Space Flight Center, NASA, Greenbelt, Md.
HCO	Harvard College Observatory, Cambridge, Mass.
IACS	Inertial attitude control system
JHU	Johns Hopkins University, Baltimore, Md.
JPL	Jet Propulsion Laboratory, California Institute of Technology, Pasadena, Calif.
Lewis	Lewis Research Center, NASA, Cleveland, Ohio
LMSC	Lockheed Missile & Space Corporation, Palo Alto, Calif.
LRC	Langley Research Center, NASA, Langley Field, Va.
NMSU	New Mexico State University, Los Cruces, N. M.
NRL	Naval Research Laboratory, Washington, D. C.

NYU	New York University, New York, N. Y.
OA0	Orbiting Astronomical Observatory
P	Partially successful sounding rocket launch
PPM	Pulse position modulation
PUO	Princeton University Observatory, Princeton, N. J.
RCAF	Royal Canadian Air Force
S	Successful sounding rocket launch
SGC	Space General Corporation, El Monte, Calif.
SPANDAR	A high-power (5 MW pulse) S-band conical scan missile tracking radar with a 60-foot parabolic reflector and a 5000 mile beacon tracking range (600 miles passive) providing digital data, with a parametric amplifier in the receiver circuit.
SARAH	A beacon transmitter (C or S-Band) flown in a sounding rocket
SPC	Solar pointing control
SRI	Stanford Research Institute, Palo Alto, Calif.
U	Unsuccessful sounding rocket launch
U Colo	University of Colorado, Boulder, Colo.
U Mich	University of Michigan, Ann Arbor, Mich.
U Wisc	University of Wisconsin, Madison, Wisc.
WI	Wallops Island Launch Facility, Wallops Island, Va.
WSMR	White Sands Missile Range, White Sands, N.M.